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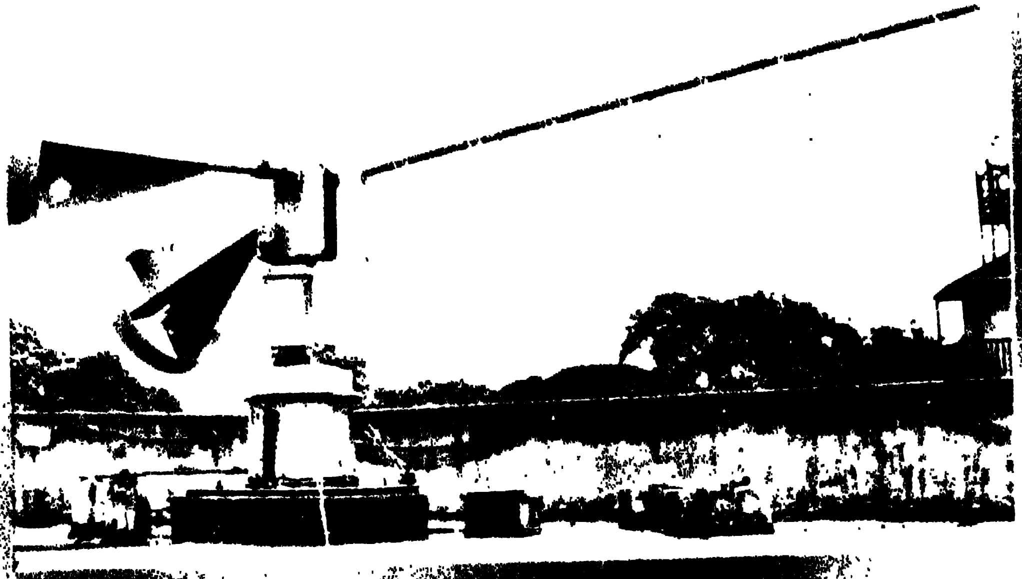

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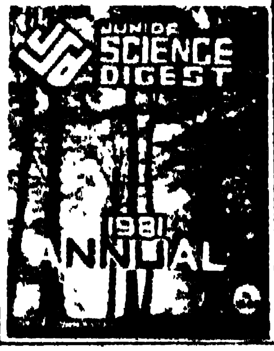	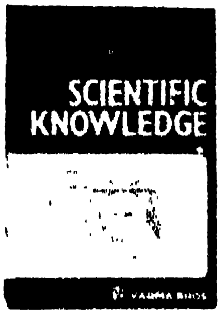	(ADD Rs. 3.50 for Regd. Postage)	

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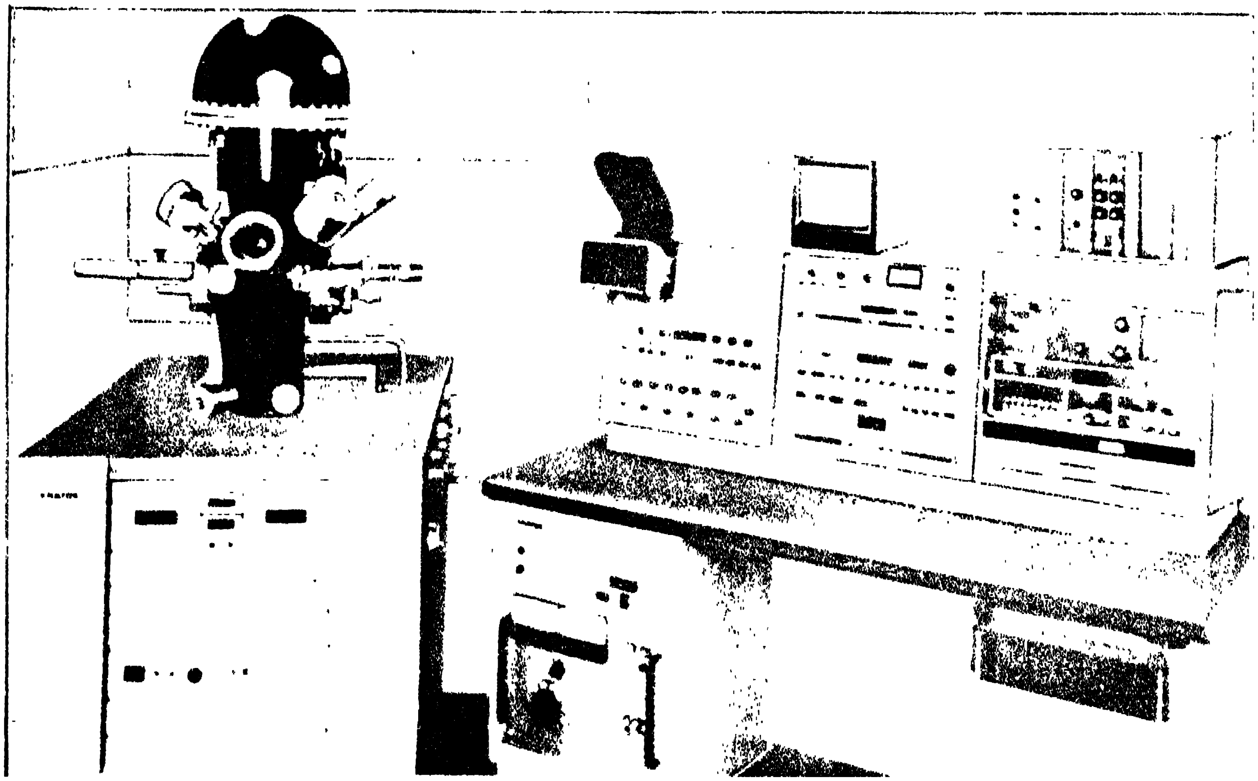

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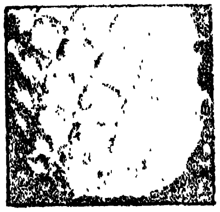

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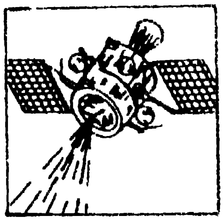

What APPLE means

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Editor: Surendra Jha

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LETTERS

MISSING LINKS IN HEALTH CARE

THOUGH Dr. S. Jha has tried to encompass a broader spectrum of the problem of health ("Health for all by the year 2000?" May, 1981), she has not taken an integrated approach. The reference to political will, which is crucial, has only been made in passing. The issue of the role of the medical establishment in contributing to the present state of affairs has also been avoided. Obviously, the over centralised, hospital-based, urban-biased and expensive health care delivery system of the state which has continued to depend totally on the modern system of medicine has not been discussed. The unholy alliance in the medical establishment of the peers of medical profession, the drug industry (including the multinationals) and politicians has to be broken to ensure any health care to the people. It is necessary to analyse the system of medical education, the role of the drug industry and the reasons for the continued neglect of traditional systems of medicine to arrive at any meaningful solution.

N. N. MEHROTRA

Department of Biochemistry
All-India Institute of Medical Sciences
New Delhi 110029

I AM surprised that Dr. Jha has used the term 'lepers' for leprosy patients. The word 'leper' is not used by general agreement, because it indicates social stigma.

K. R. PRASAD

5-5-317 (I floor)
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STEREOTYPED EDUCATION

DR. GOPALAN's article on Undergraduate Research Opportunities Programme (Viewpoints, May 1981) highlights by contrast that our undergraduate engineering educational system needs modifications. The present memory-based stereotyped system is insufficient to evaluate a student's creativity, innovativeness and ability to face unusual situations. It only certifies his memory and ability to work hard on spoon fed material. It is a known fact and my own experience that engineering students certified as average or poor can do better than their distinction-holding colleagues in their dissertations (or project work), where they have considerable freedom to carry out the work.

Unfortunately many of our renowned institutions seem to have overlooked this aspect and still believe in shortlisting applications for post-graduate courses on the basis of academic record which is often not a true measure of a student's calibre (at least, as far as engineering fields are concerned). It is very essential, therefore, to reform the present system for undergraduate engineering education in order to obtain better performance from engineering graduates in their respective fields as well as to pick right talent for higher education and research.

V. R. SULI

Karnataka Regional
Engineering College
Surathkal (Karnataka)

NEPTUNE FINDER CHART

THE ordinate (that is, the vertical axis) in Fig. 3 on p. 68 in my article (Skymap, May 1981) corresponds to the declination of the planet Neptune. The range of that ordinate should be −20° to −25° (running downwards) instead of +20° to +15° as printed. I am sorry for this error.

N. C. RANA
Tata Institute of
Fundamental Research
Bombay 400 005.

FULL DOCUMENTS, PLEASE

WE WOULD like to congratulate you on periodically publishing reports on various documents related to science and technology plans, policy and education. In particular, it was a commendable job to publish excerpts from the Nayudamma review committee report on post-graduate education and research in engineering and technology (September 1980) and the science and technology chapter of the Sixth Five-Year Plan (April 1981). While the reports have been timely, relevant and informative, we, however, feel that a serious and meaningful discussion cannot be carried out on their basis. Full documents are needed for this purpose. And these documents are generally not available in most of the libraries. Also, it is very difficult to get these from concerned departments/ministries unless one has contacts in the right quarters. Besides, the documents are very expensive, and beyond the reach of common men. The government or the concerned authorities should, therefore, make the documents available free of cost or at nominal prices.

S. M. KAUSHIK
R. V. JASRA
K. P. KOTHIYAL

Indian Institute of
Technology
New Delhi 110029

FAMILY PLANNING TARGETS

THE Sixth Plan lays down the goal of family planning as 2.3 children per family or a birth rate of 21 per thousand, and concludes that "the family planning programme must rise above all controversies, and should be accepted as a national programme by all sections of population" ("Health and family planning in the Sixth Plan", May 1981).

But experience of the past 34 years shows that neither this pious thinking nor cash incentives of Rs 100 per male or Rs 200 per female, undergoing vasectomy or tubectomy, will be effective. If the government honestly desires to reduce the birth rate, it should provide, by legislation, that if *a third* child is born of any parents after a specified date (one year after the enactment comes into force), both the parents, irrespective of their class, caste, religion or sect, will be permanently disqualified to hold any post or service in the central and the state governments (including the armed forces), public sector undertakings, local bodies, corporations and educational institutions aided or recognised by the government, banks, and factories and companies as defined by the Factories Act and the Companies Act. They will, of course, be disqualified to contest any seat in the central and state legislatures or local bodies.

A. B. KETKAR

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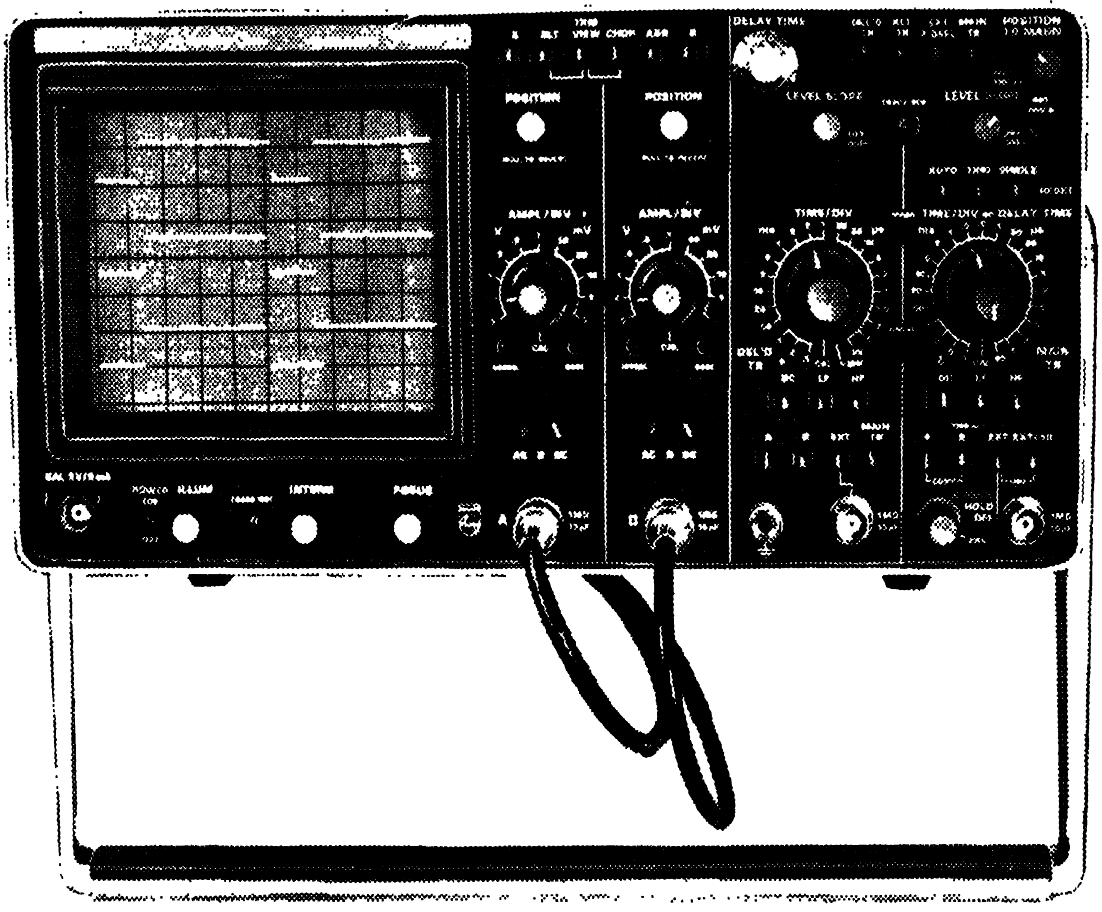

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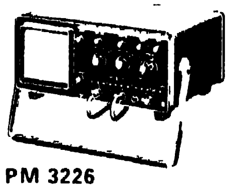

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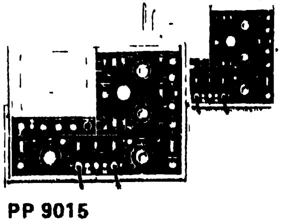

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VIEWPOINTS

On technological self-reliance

THREE recent events should make us think seriously about the pace of progress towards technological self-reliance! The first relates to the prolonged delay in the supply of enriched uranium fuel for the Tarapur nuclear power plant, exposing our vulnerability in the vital segment of the energy sector which may play an increasingly important role in future. This vulnerability arises from our dependence on a "critical technology" or strategic material which will not be exported or sold.

The second pertains to the total failure of the Fourth Session of the UN Conference on an International Code of Conduct on Transfer of Technology sponsored by UNCTAD and held from 23 March to 10 April 1981 at Geneva; the conference decided to refer the matter to the UN General Assembly to take appropriate action, and thus ended nine years of negotiations among developing countries, developed countries and socialist countries on a code which would provide the sale of technology on fair and equitable terms to developing countries. It may be noted that the USA (supported by the UK, West Germany and Switzerland) has been opposed to the concept of such a code or the need for it.

The third is the launching of Rohini-II satellite atop a four-stage rocket on 31 May 1981. India is the sixth country in the world to launch artificial earth satellites. It has achieved considerable progress in developing miniaturised and sophisticated instrumentation, a telemetry system for storing and sending data for "on-line" ground-based computers and a rocket technology with more than 100,000 components. There seems to be some weakness in the trajectory control technology, but the event reveals what we can do if we decide and mean to do what we decide.

However, it is one thing to achieve a success in a few (public sector) research and development projects where cost and time are no considerations and in some private sector adaptive research projects. It is qualitatively different to obtain a regular flow of R&D intentions and discoveries (process and product design know-how) from time- and resource-bound programmes and their successful application/commercialisation. Should and can India achieve this?

Why do we need to deploy new and more efficient technologies on an increasing scale and on a continuing basis? The following reasons may be given: (1) to supply to every one a widening range of goods and services—better, safer and cheaper—in an increasing volume over a finite time horizon; (2) to improve the quality of life both at home and at the work place; (3) to improve our competitive strength in international trade of goods and services; and (4) to improve the defence capability of the nation by not permitting the potential aggressors to acquire decisive superiority in the weapon systems, weapons, communication and other technical facilities.

The first is really a development goal accepted by all developing countries. The second is also a development goal, though it is somewhat less pronounced in developing countries than in developed countries. This goal has many components and their number continues to grow. We shall mention here only a few which have already found expression as a felt need by one group of society or another in our country: (i) prevention of environmental pollution, (ii) prevention of damage to ecology and the rehabilitation of ecology wherever damage has already occurred and is reversible, (iii) occupational health and hazards safety, (iv) lightening arduous manual labour, (v) labour participation in decision-making in matters directly affecting them, (vi) reduction in monotony and boredom of specific work activities, etc. The realisation of these two objectives require the introduction of new products and technologies which will increase land and labour productivity and energy and raw materials efficiency. It will also require technologies which will substitute scarce inputs by abundant inputs and non-renewable resources by renewable resources where technically and economically viable. It will also require the economies of scale, technological economies as well as economies of indivisibilities, specialisation and standardisation.

In order to achieve these two objectives, we may pursue simultaneously three different means or routes: (i) a quantitative increase in the deployment of basic inputs—land, other natural resources endowments, reproducible capital, that is, plant and machinery and labour; (ii) a rise in the efficiency or quality of basic inputs; and (iii) mobilisation of technological economies and economies of indivisibilities (R & D, functional specialisation of labour and equipment, etc). There is no doubt some room for increasing the supply of goods and services by employing the idle labour and supplying them with existing types of plant and equipment. Some land presently inaccessible for agriculture can be made accessible. But this has limited potential. Once these two resources are exhausted, economic and social development will have entirely to depend on the other two routes—increasing the efficiency of basic inputs and exploiting economies of scale.

India also will have to depend, in the main, on the same two routes. We need to increase productivity of land by more irrigation and better water management, high-yielding disease-resistant varieties of seeds, optimal doses of fertilisers, judicious use of chemical pesticides in the framework of integrated pest management and better cultural practices. The protein content of pulses and cereals will have to be increased by genetic manipulations. But all this will require the introduction of improved and new technologies in the farm sector.

India's oil import bill, which is already Rs. 5,000 crores, will absorb 80 per cent of her export earnings. We need also to import a large variety of other items - raw materials, equipment and machinery, and weapons for defence. We are thus faced with a massive deficit in the balance of trade. A massive export drive is a "must" for our country. We are also interested in exporting more value-added products and diversified product groups. The foundation of such an export drive is an edge in price and quality over our competitors. A competitive edge in the export drive can only be provided by a stream of new and better technologies sustained over a long period. Similarly, we need technologies to produce defence needs, especially weapons.

Technology markets: open features

Although most of the tens of thousands of technologies are in "public domain", that is, they are available without payment of fees or royalties, a large number of technologies are kept out of the public domain. Many of them are patented with the legally recognised ownership rights. Export of some of them, especially those with applications in the military field, space exploration, nuclear energy and computers are banned by the US and other advanced countries. Others are kept secret, though they may not have been patented. Inaccessible technologies and some of the patented technologies are not sold by the owners in three cases: there is no competing product in the market (for example, Polaroid cameras did not have any competitor until recently); the owner uses the production process which gives a unique quality to the output or which offers a unique advantage in the form of reduced unit cost; and the owner prefers to sell the output instead of the technology in spite of tariff barriers because he believes that foreigners will have to buy his output, or export markets are unimportant, or he cannot protect the secrecy of his process (for example, a few life-saving drugs). The objective in each case is to make monopolistic profits. India has no choice but to develop these three kinds of technologies if she wishes to have them—critical technologies on the banned list, patented but inaccessible technologies and unpatented but inaccessible technologies. The R & D in public sector has achieved its most notable success in these three categories of technologies.

The rest of the patented technologies are available for sale. Payments for proprietary technologies should be distinguished from payments for the use of trademarks and brand names.

Concealed features

The seller of a technology has an overwhelming bargaining power. There are also some important but concealed features of the technology market of which the buyers from developing countries are the biggest victims.

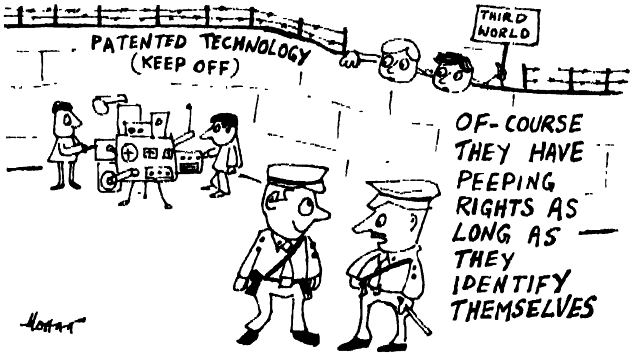
The concealed features are usually in the signed agreements. They are in the nature of restrictions imposed on the buyer of technology and usually discussed under the title of "restrictive clauses". Those restrictions represent a potential loss to the buyer and/or his country. Some of them are: (i) limitation on volume of production or capacity; (ii) requiring the buyer to grant back to the seller or his representatives any improvements made in the technology bought without offsetting consideration; (iii) restricting the buyer to undertake any R & D work to absorb or adapt technology or to develop new products, processes or equipment; (iv) territorial or quantitative restrictions on exports; (v) imposing equity participation; (vi) tying up sale of some or all elements of plants and equipment and engineering and technical services and sale of some of the raw materials, intermediates or components, and (vii) imposing regulation of prices of goods and services on the buyer of technology.

Another hidden feature of technology markets is the *transfer payments* which arise from one form of tie-up arrangement or another. A technology seller imposes on the buyer the obligation to purchase part of the equipment from him. If the price of this equipment is \$ X in a competitive market, the technology seller imposes the price \$(X + a). The \$ a is the transfer price of the part of machinery which he has compelled the technology buyer to purchase from him.

The leverage of the technology seller may be threefold: (i) he may be a monoplistic or an oligopolistic supplier of that kind of technology, or production based on it; (ii) the deployment of technology requires the use of an intermediary or piece of equipment which he alone manufactures ; (iii) the productive facility embodying the technology requires raw materials which are available in a few countries and are controlled by him. The last instrument can usually be wielded by a large multinational firm. This leverage is deployed against buyers of technology from developing and developed countries.

A developing country is more vulnerable and more leverage can be exercised against it. First, domestic production is more limited; many more intermediates and raw materials need to be imported. A technology buyer does not often know the alternative sources from where he can get them. A developing country is not usually able to fabricate any part of the plant and machinery. The country is short of investment funds and foreign exchange. And the offer of equity participation falls on receptive ears. Most developing countries lack design engineering services and other technical services for engineering designs and the purchase and installation of machinery and for construction of the project. Thus, wide opportunities are available for the seller of technology to provide tie-up clauses or packaged deals in the agreement both at the construction phase and the operational phase of the investment. In India, the following channels are used to obtain transfer payments.

The seller of the technology will insist on providing a package deal: a technology (a software), plant and machinery, design engineering services for plant, foundations, construction, detailed drawings, supervision and production start-up, etc. The package deal has two consequences. First, the assessment of the deal becomes impossible in the absence of prices of individual components. Second, the need for a consulting engineering firm which alone can assist the buyer of technology in the assessment of the deal and minimising the costs is eliminated. That is why developing countries have asked for "unpackaging" such transactions as one of the demands.


PATENTED TECHNOLOGY (KEEP OFF)
THIRD WORLD
OF-COURSE THEY HAVE PEEPING RIGHTS AS LONG AS THEY IDENTIFY THEMSELVES

There is a tying-up of sale of some equipment and some intermediates or components. In engineering and some other industries, the proprietary technology is embodied in some pieces of machinery called "non-standard equipment". The sellers of technology provide the designs of non-standard equipment to the consulting engineering firm chosen by the buyer of a developed country. But they usually insist on providing "non-standard" equipment to the purchaser of technology from developing countries including India.

A productive facility requires several inputs on a recurrent basis. Some of these inputs are scarce raw materials not found in India, and sophisticated intermediates or components which are not manufactured in our country. The seller of technology offers to enter into agreement with the buyer to sell the required inputs especially those in which he is the monopolist–oligopolistic supplier.

The seller of a technology often insists on equity participation in the business of the buyer of technology

Such participation often is aimed at obtaining the control over the sources of imported inputs. When the seller of technology with equity participation is a multi-national firm, the opportunities further widen as the multi-national firm could undertake an obligation of exporting a part of the output from the proposed plant.

Transfer pricing and profits resulting from them have been as old as the multi-national firms. The cost of importing technologies has already reached a high level. The ESCAP study of 1976 stated: "The direct costs of know-how, already around $ 1 billion for developing Asian countries, are expected to double by the end of this decade. In addition, there are the indirect costs of tie-in arrangements for import of intermediaries and capital equipment resulting from ownership ties of technical requirements, etc and, perhaps more serious, the penalties of inappropriate products and processes." And no one has estimated indirect costs or transfer payment. There are also the social costs of inappropriate processes and products and other features of technology.

Technological self-reliance

Import of technologies entails heavy costs for India. Royalties and fees constitute only a small visible tip of the iceberg. The invisible portion of the iceberg encompasses transfer payments and social costs The latter include the inability of our technologies to provide a competitive edge to goods and services in export markets, direct restraints on exports of goods and services based on proprietary imported technologies, defence equipment based on inferior technology, lack of rapid diffusion of imported technologies inherent in their proprietary character and other restrictive conditions, lack of incentive for innovation in the machine-manufacturing industry, penalties for inappropriate products and processes and emigration of a large proportion of brilliant research-oriented scientists and technologists.

India, on the other hand, has the potential for generating technologies mainly because of the massive size of population (market), a good stock of scientific and technically trained personnel and a fairly good size of diversified industrial base—not on a per capita basis but on the basis of the order of total magnitudes. Our total stock of scientific and technical manpower is estimated at 2.5 million. India's 119 universities, affiliating about 1650 colleges, five institutes of technology, 150 engineering colleges, 350 polytechnics and 100 medical colleges produce annually some 150,000 scientifically and technically qualified personnel. About 130 specialised research laboratories/institutes have been established under the aegis of the Indian Council of Agricultural Research, the Council of Scientific and Industrial Research, the Indian Council of Medical Research, Departments of Atomic Energy, Science and Technology and Space, and the Defence Research and Development Organisation. In addition, there are over 600 in-house research laboratories of public and private enterprises. Added to them are some 150 engineering consultancy organisations, employing over 20,000 engineers and technologists. The expenditure on science and technology is, at present, close to 0.6 per cent of the gross national product.

These figures, plus some of the R & D successes noted earlier, do indicate that the country can make rapid progress towards technological self-reliance. Technological self-reliance should not be confused with technological self-sufficiency. No country in the world, not even the USA or the USSR, is technologically self-sufficient. Technological self-reliance is the mix of indigenous development of technologies and judicious import of selected technologies.

We may classify the process of technological self-reliance in five groups of related activities or in five modules on a functional basis. Three groups involve research or inventive activity, while the last two groups are in the nature of services. They are:: (i) R & D establishments (advanced), (ii) applied research laboratories, (iii) adaptive research organisations, (iv) design engineering and other related services, and (v) structural and construction engineering services. These modules represent degrees or levels of technological self-reliance.

The first module demands the highest skills for it generates new product or process know-how on a laboratory scale, assists in building a pilot plant or a prototype and guides Group 4 in designing a commercial scale facility during the initial period. The first group also helps in bringing about *significant* or *major* improvements in existing technologies. It has also the responsibility of developing new innovations and major improvements using the imported technology as a starting point.

The imported technology needs to be modified to suit a host of local conditions—scaling down the size to suit smaller markets without increasing unit costs, modification of equipment to suit local raw materials, modification of the process to suit the local climate, and changes in product design to correspond to local conditions. A major consideration in adaptation is the relative cost of labour and capital. This work is carried by adaptive research units.

Design engineering and related services constitute a vital element both in technological self-reliance and the regulation of imported technologies. Therefore, the functions of this group will be examined in the next section. Construction and structural engineering services undertake the task of laying the foundations and constructing the buildings of the factories.

India has the potential of achieving basic self-sufficiency in design engineering and related services and construction and structural engineering services. The same is more or less true for adaptive research and applied research on the basis of basic knowledge of technologies (Groups 3 and 4) where the major constraint is in the nature of available technical facilities and not the capability of our manpower.

Our main bottleneck is advanced research and development for creating new processes and product know-how. The time-scale in this work often stretches from medium up to long term. And the resources required are often enormous. Only the government and large houses in the private sector are potentially capable of undertaking such work. The performance of the private sector in creating new process and product know-how is even poorer than in the public sector in terms of investment, operating expenditure or results obtained.

The thrust for creating new technologies is absent in India's private sector. The multi-nationals keep their R & D facilities basically in their home countries and peripherally in other advanced countries because R & D facilities are their basic source of monopoly power. The location of the most important component of their activities require maximum security from nationalisation on the one hand and from indusrial espionage on the other. They cannot be sure on either count in India. India cannot provide them as good an infra-structure or environment for research as the home country. And why should they accept anything second best for their basic source of monopoly power? Thus, the large companies controlled by the multi-nationals have no incentive to invest resources in R & D.

Large companies effectively controlled by indigenous entrepreneurs have evolved on the basis of imported technologies. These entrepreneurs have in many companies entered into financial collaboration with giant multi-national firms. The equity participation by multinationals in these companies does not affect the operational control by indigenous entrepreneurs provided some unwritten but clearly understood rules of the game are adhered to. The rules of game appear to be as follows: (i) the Indian partner should run the company efficiently and make respectable profits, that is, ensure a good return on equity, (ii) preference should be given to the foreign partner—a multi-national—in placing orders for equipment, purchase of technology, procuring supplies and services from abroad, (iii) the "best customer treatment" should be granted to the multi-national if it purchases the output of the company, (iv) competition with the multi-national partner should be discouraged by keeping out of its zone of activities and influence (market), and (v) investment in advanced R & D should be kept to a low level as "a matter of prudence" because of inherent risk, a long gestation period and high costs.

The second and third rules of the game generate transfer payments in addition to profits. The fourth rule will restrain export while the fifth perpetuates India's technology dependence. The psychological make-up of Indian entrepreneurs is such that they have no objections to the fifth rule of the game. The second, third and fourth rules may occasionally be perceived as "concessions". However, they are usually perceived as *quid pro quo* for not sharing the operational control of the company. The absence of the time-bound programme of adequately funded projects with personal accountability, low status and rank assigned to personnel working in R & D laboratories, the lack of autonomy, the absence of the system of rewards and penalty, discouraging of initiative, inadequate facilities, a feudal hierarchic milieu instead of interpersonal relationship, based on equality on intellectual matters and recognition of ability, outdated administrative procedures, petty ego conflicts instead of mutual tolerance and co-operation and the lack of national recognition of R & D activities are among the key factors adversely affecting R & D activities in the public sector R & D establishments.

Consulting engineering firms—the strategic link

It was stated earlier that the product and process design engineering competence institutionalised in the form of consulting engineering firms in India and the western countries constituted the strategic link in the process of acquiring technological self-reliance. Consulting engineering can be broad based and provides services to a broad spectrum of industries. It can only be highly specialised in design engineering in a group of inter-related processes and/or products.

The establishment of comprehensive plant design and engineering services will result in several benefits to developing countries apart from securing valuable savings in recurring foreign exchange expenditure. The services will constitute the most important source of information on alternative productive process technologies, alternative sources of proprietary technologies and alternative sources of plant and equipment. They will be able to choose and, if necessary, arrange for adaptation of imported technologies to suit local, physical and factor endowment, industrial and technological infrastructure, scaling down the plant to the size of the market, etc. They will undertake more effective and speedier diffusion of technology.

Plant design and engineering services are the depository of knowledge on technologies in the public domain. Eventually, they will strengthen the bargaining power of indigenous entrepreneurs.

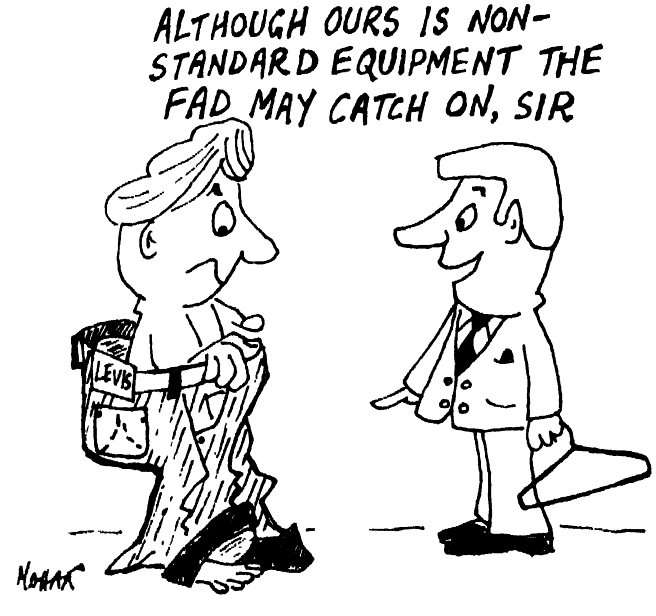
They can identify R & D projects of potential commercial value and assist in fabrication of pilot plants and prototypes. They can prepare designs and drawings for scaling up a laboratory bench process to a commercial scale. They can engineer prototypes for commercial production. They can transfer new product and process know-how to industry users. Thus they constitute a vital link between R & D establishments and machine manufacturing industry, and between machine manufacturing industry and user-industries for the purpose of converting the software into hardware embodying new and improved technology and diffusing this technology among the relevant industries.

Consulting engineering services can also provide valuable inputs in the planning process in the form of realistic estimates of project costs and gestation periods of construction of industrial projects, and in realising rated capacity outputs and the assessment of linkage requirements. They can also help in preparing and assessing mid-term or long-term science and technology programmes. Product and process design engineering competence is indispensable for realising technological self-reliance and for judicious regulation of import of technologies.

Identification of priorities

The first task in the process of realising complete technological self-reliance will be to identify sub-sectors of economy in which we should like to achieve indigenous capability. The sub-sector in this case will mean a well-defined group of inter-related processes or product technologies or technologies founded on common or similar core processes. A classification of technologies is a job of experts. Consequently, we can only present here a procedure to be followed by way of an illustration. First of all we need to scrutinise those "critical technologies"—whether proprietory or not—which are inaccessible to us and identify some of them which we deem to be vital for us and the future generations. This will include technologies in the fields of nuclear energy, outer space, certain weapons systems, and highspeed computer and microprocessors.

The next area of importance is probably the energy sector, excluding nuclear energy. We should, for example, seriously examine the prospects in the field of solar energy, synthetic fuels, gasification of coal and derivation of hydrocarbons from plants. The key issues are the available options, time-scale, the initial technical base start R & D work and resources.


ALTHOUGH OURS IS NON-STANDARD EQUIPMENT THE FAD MAY CATCH ON, SIR
LEVIS
Honar

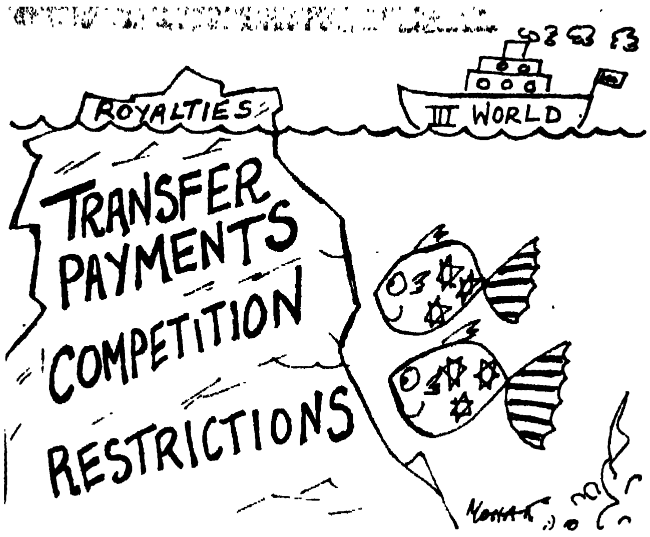
The third sector which certainly deserves our attention is agriculture with special reference to genetic modification of seeds, getting higher protein content, higher yields and resistance to pests and diseases. Crops in their order of descending importance should be identified.

Fourth is the machine-making industry which should be greatly expanded and upgraded to meet our growing needs so that we may raise the efficiency of our reproducible capital. Fifth, the exploration of the possibility of substituting those natural raw materials which are either imported or are in scarce supply or likely to be exhausted in the next decade or two. And the sixth priority should go to the search for alternative raw materials for manufacturing white printing paper and newsprint.

The above illustrative procedure is meant to indicate the mode of identifying priorities. The final decision on priorities will be taken by the Planning Commission. A group of experts familiar with the group of process or product know-how can prepare detailed R & D projects, including a phased programme of research and development activities—time, and resource-bound—spread over a specified length of time. The mobilisation of the "critical mass" of resources should be ensured in such project planning. Planning of R & D has, basically, to be done at the micro-level because the macro parameters are not available except for allocating a certain percentage of total resources to R & D activities which may be fixed to rise up to a fixed percentage, say 1 to 2 per cent, of the GNP by the end of the Sixth Plan. The scale of our efforts is more or less determined by the resources available on the one hand and the priorities approved by the Planning Commission on the other hand.

Regulation of imported technology

Since the negotiations between the developed and developing countries on a draft code of conduct on transfer of technology have completely broken down, India has no course open except to pass comprehensive national legislation regulating transfer of technology. The principal objectives of such a legislation should be: (a) to establish general equitable rules for the international transfer of technology, taking into consideration special needs of India and the legitimate interests of technology suppliers and technology recipients; (b) to ensure that the import of technologies will be consistent with India's goal of achieving technological self-reliance in general and autonomous generation of technologies in particular; (c) to strengthen the bargaining power of individual technology recipients; (d) to eliminate or minimise indirect costs and other social costs such as would result from environmental pollution, damage to ecology, occupational health hazards, the restrictions on diffusion of imported technologies within the country, emigration of research-oriented engineering personnel, etc; and (e) to enhance the contributions of imported technologies to the identification and solution of social and economic problems of India; to facilitate an increase in the international flow of technological information, particularly on the availability of alternative technologies as a prerequisite for the assessment, selection, adaption, development and use of technologies; and to strengthen the national technological and scientific capabilities, for selecting imported technologies and adapting them to suit local conditions and assimilating them into the national economy.



The draft outline for an international code of conduct on transfer of technology originally submitted on behalf of the experts from the Group of 77 proposes some 25 measures for regulating transfer of technology transactions. It further proposes prohibition or control of some 40 restrictive trade practices prevalent in the transfer of technology transactions. The latest draft international code of conduct on the transfer of technology which was the basis of the April-May 1981 conference which ended in total failure only provides for the scope of national regulation encompassing finance, renegotiations of the technology acquisition agreement, technical aspects, organisational forms and mechanism covering 17 issues. The chapter dealing with restrictive trade practices—though there was no agreement on the title of the chapter—lists some 20 practices under different headings. These headings are draw-back provisions, challenges to validity, exclusive dealing, restrictions on research, restriction on use of personnel, price fixing, restriction on adaption, exclusive sales or written agreement, tying arrangements, export restrictions, patent pool, restriction on publicity, obligation after expiration of industrial property rights (payments and others), restrictions after expirations of arrangements, limitation on volume of production, quality control, obligation to use trade marks, requirement to provide equity participation in management, unlimited or unduly long durations of arrangements and limitations upon use of technology already imported. Several model national regulations on import of technology and on prohibition of restrictive trade practices are available. They include legislations regulations from Japan, Argentina, Mexico, Republic of Korea, etc. We can frame appropriate legislation in areas suited to our objectives and conditions.

National policy on technology

A careful perusal of Chapter 19 of the Sixth Plan (1980-85) gives the impression that the Planning Commission has not yet given any serious thought to the formulation of a national technological policy and what are even its relevant variables. It has merely maintained a status quo. It is quite probable that it did not have the time to examine the issue because, the concepts, variables, norms and measurement have all to be worked out. Hopefully, it will do so now since the Sixth Plan has been approved by the National Development Council. The following basic issues need to be considered.

A. A review of the construction and structural engineering capability with a view to filling in gaps and upgrading quality. This should be co-related with corresponding educational and training facilities and industrial capacity and pinpoint weaknesses and corrective measures.

B. A review of consulting engineering capability with a view to filling in vacancies and upgrading quality forging close links between consulting engineering and R & D personnel for assessing commercial prospects of research, scaling up of laboratory-scale and pilot plant results and commercialising new technologies, between the former and machine-manufacturing industry for incorporating new and improved technologies, and consulting engineers and entrepreneurs for selection and evaluation of technologies and speedy diffusion of new and improved technologies

C. A review of applied research laboratories and adaptive research laboratories and R & D outfits to find out the facilities and capabilities and the present status of their activities, to identify priorities for the work programme and their programmes for expansion, and to introduce a regular reporting system to gather relevant data and information.

D. Introduce policy and legislation banning restrictive trade practices in import of technology with special reference to export restrictions, ban on diffusion of technology within the country, "unpackaging", tie-up sales, etc.

E. National policy and legislation to regulate import of technology with a view (i) to prevent aborting of national efforts to develop indigenous technologies; (ii) to provide positive incentives, efforts and assistance for promoting development of indigenous technology; (iii) to ensure the selection of imported technology which is most suitable to local conditions; (iv) to prevent the induction of hazardous, polluting and ecologically harmful technologies; (v) to eliminate or minimise the prospects of transfer pricing and payments (indirect costs); (vi) to strengthen the bargaining position of technology recipients, and (vii) to eliminate or minimise other social costs of imported technologies.

F Establishment of registration of imported technologies

G Establishment of registration of Indian proprietary technologies

H Establishment of registration of (i) indigenously improved technologies, and (ii) new proprietary technologies.

I. Establishment of registration of (a) R & D projects for discovering new technologies, (b) research projects for improving technologies, and (c) adaptive research projects

India's present technology import policy acts as a drag on indigenous R & D work on generation of technologies especially in the private sector. Our big houses are very large but they have generated few new technologies This is not because of the lack of either capability or risk-bearing ability or resources. It is because of the *technology import* policy combined with the equity participation of the generators of technology abroad- the multinationals, the colonial orientation of big entrepreneurs (of which they are happily unaware) and the lack of positive thrust by the government for generating technologies

India places less restrictions on import of technologies than Japan does; and Japan is an advanced country competing with the USA, West Germany, France and other developed countries of Europe on an equal footing. The mode of importing technology is the second vital issue, and, in India's case, perhaps the most important What India in practice absorbs is a production know-how while Japan absorbs the know-how (a software), digests its novel features and the logic or rationale behind it, masters the rationale, and incorporates it within its R & D facilities; it then uses it as a base not only for adaptation but basically for R & D activities for improving the imported technology and for discovering new product and process technologies, that is, finding new applications. It ensures the diffusion of the same technology within Japan. Japan does not need to import the improved version of the same technology or new applications that flow from it.

In India, no attempt is made to *diagnose* the new features of technology with a view to assimilating them in the stock of *technological* knowledge. It is here that India will have to make a revolutionary break with the past with new rules and regulations combined with incentives and assistance built in as conditions to technology-import licence as well as other relevant legislation. Some new mechanisms may have to be devised for this purpose. In advanced countries, each large house is a *store-house* of technical know-how which it expands. The expansion of technological know-how is the foundation of the expansion of production, renovation or modernisation.

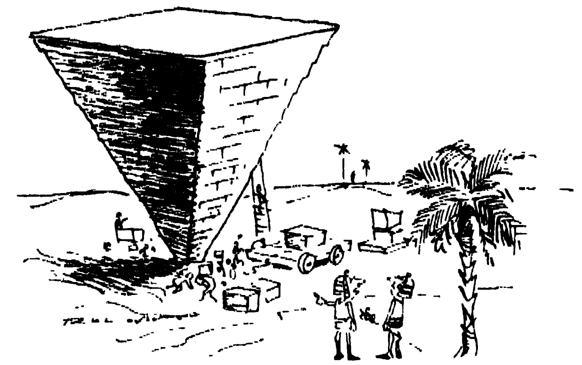
Some of the biggest houses in India (for example, Birlas and Tatas) may not be granted licence to import technology and may be allowed to expand only on the basis of the technologies generated by them. Other large houses may not be granted technology-import licences in areas in which they have already imported technologies. A surcharge may be charged on corporations which have not spent a minimum percentage on R & D R & D facilities of a minimum scale may be made obligatory for the corporation with some minimum investment in a productive facility. Then, the most urgent as well as important task of the Planning Commission is to organise an experts committee to recommend on how imported technologies can be assimilated into the stock of technical knowledge of the company and the country and how the expanded technical knowledge can be used for improving the imported technology and discovering new technologies. There is yet no sign that the policy makers are aware of the issue

It is vital to improve R & D in the private sector and generate technologies since entrepreneurs have no constraints which the public sector suffers from.

If the public sector is to be an effective generator of technologies, several constraints will have to be removed. First, the compensation will have to be at much higher level; and the system of rewards and sanctions will have to be introduced Second, administrative and accounting procedures will have to be drastically modified. Third, it must have the maximum autonomy both from the bureaucracy as well as the administrative hierarchy of a public sector enterprise. Fourth, time and resource-bound programmes have to be introduced; and the principle of personal accountability should be used. Fifth, research workers, irrespective of differences in their salaries, get best results in an atmosphere of 'academic' or intellectual egalitarianism and non-interference from "superiors" who are generalists or do not share their specialities In India, the bureaucratic heirarchic approach and constant interference tend to destroy the initiative and free inquiry so important in R & D work. Sixth, in R & D projects, the scope for spreading resources thinly is limited. The principle of the application of the "critical mass" of resources must be the invariant guide in allocation of resources. We should strive to achieve these six conditions in the R & D components of the public sector if we wish to make it productive as well as cost-effective

PRAFULLA SANGHVI

Dr. Sanghvi, a member of the Monopolies and Restrictive Trade Practices Commission, New Delhi, was earlier with the United Nations Development Programme in New York dealing, among other things, with technology transfer and development. He has a Ph D in economics from Cambridge University, England.



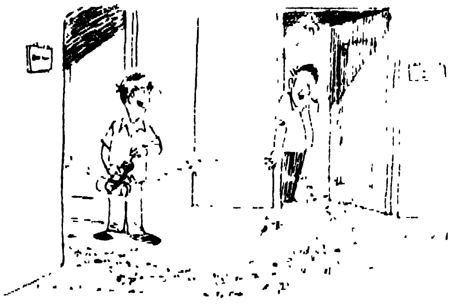
"You shouldn't have commissioned that architect to build the pyramid, Your Excellency He is a bit too unconventional."

"Every time we pass this way you do it! You very well know it's one of those dummies put by the game sanctuary authorities to attract tourists."

This World of Science!

by R. K. Laxman

"You like it? Good! I'll tell you what it is, saw dust, minced India rubber, shredded paper bits, boiled rags..."



"The great thing about this new insect spray is it doesn't kill It quietly drives out the insects!"

...and of Scientists

IRVING Langmuir, who won the 1932 Nobel Prize for chemistry for his work on surface chemistry, could collect children around him with the ease of a Pied Piper. When people came visiting—or when the Langmuirs went visiting—Langmuir would be found with the children in the backyard, as likely as not, where he would show them all sorts of tricks. He used whatever was at hand—sticks, stones, pieces of string, buckets and hoses. He might tie a stone at the end of a string and say, "Now, let's talk about the pendulum." Or he might whirl a pail of water over his head while the children wondered why the water did not come pouring out of the upside-down bucket. Or he might do the poker-and-compass trick, giving the iron poker a good hard knock with a hammer to loosen its crystals, then magnetising it. (This trick got him into trouble with a sister-in-law one day when he knocked the brass handle off a prized poker.) If the child was too little to talk or listen, Langmuir would simply bounce him up and down on his knee, chanting:

"In phase out of phase,
"In phase, out of phase."

Langmuir did a lot of work on the effects of hot metal surfaces on gases. His finding that the rate of evaporation of tungsten atoms from the glowing filament of an electric bulb decreased when an inert gas was used in the bulb, instead of having a vacuum as was usual at that time, resulted in prolonging the lifetime of electric bulbs.

LANGMUIR's lecture at Budapest, during one of his lecture tours of Europe, became famous, not for its content, but for its preamble. As the scientists Gabor and Szilard tell it, the audience at the University was packed with high-ranking Hungarian nobility and at least one member of the Hungarian royal family. Each speaker, before beginning, turned obsequiously to the formidable assemblage of aristocrats, addressing each in turn by his full title, so that the normal "Ladies and gentlemen" kind of introduction turned into a long-winded speech by itself. It was all very tiresome, naturally, but protocol was protocol.

When it was Langmuir's turn to speak, he got up and, with the characteristic bluntness of a man who had never learned the art of small talk, began: "If you take a tungsten wire and .." Before he could finish the sentence, a brief burst of spontaneous applause broke out among the delighted scientists, who then repeated all over Europe the story about the straightforward American.

C. UBEROI

IN spite of his preoccupation with science, Albert Einstein found time to play the violin. He could hold his own in recitals with top professionals. Things did sometimes go wrong, however. Once, playing a duet with the great pianist Arthur Schnabel, he fumbled at one point, and the man for whom mathematics was a second language was rebuked by Schnabel, "What's the matter with you, Einstein, can't you count?"

B F CHHAPGAR

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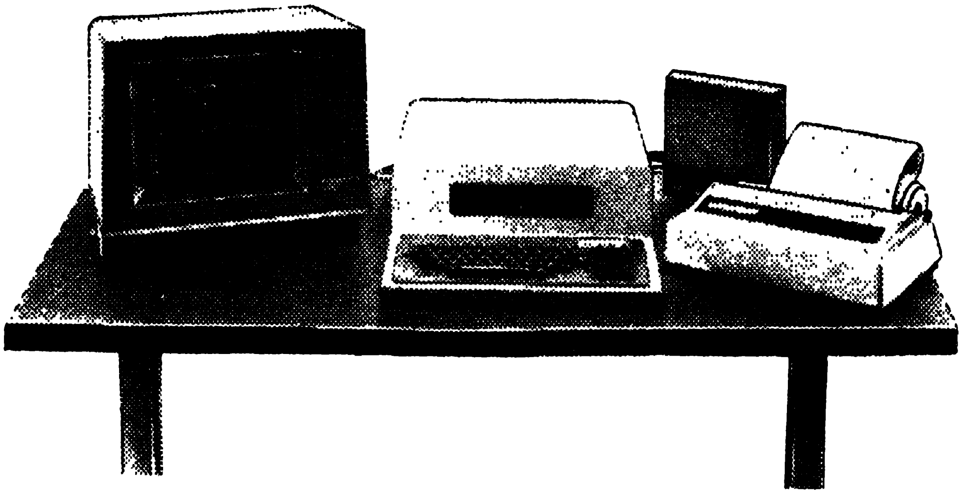

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SCIENCE SHAPES LIFE

JAPAN'S NUCLEAR SPILL

On 7 March 1981, an estimated 15 tonnes of radioactive water in a Japanese nuclear power plant overflowed, covered the floor of one room and went splashing down its long corridors. A small portion of it flowed into a tank connected to an adjacent laundry room. Through cracks in the room it seeped into the ground and through a storm sewer line reached a fishing bay.

The spill has apparently caused no harm to the fish or the men and the incident was covered up. Then, a month later the Japanese health authorities discovered radioactivity in shore sand and in an inedible weed during routine sampling; this brought the incident to light. The accident was due to someone having forgotten to shut off the intake valve.

In 1975, it has now been found, 35 workers had been exposed to an unknown amount of radiation in a similar spill and in January 1981, 23 workers were exposed to radiation during repairs. The furore caused by the latest discovery has led to the resignations of the president and the chairman of the Japan Atomic Power Company.

Japan already has 22 operating reactors and plans for 35 more by 1990. Whether information on such potentially hazardous spills is given in time or not becomes a major problem, especially after investigators have now also learnt of four other undisclosed spills and accidents at the plant over the past five years.

RED PUTS A STOP TO CHICKEN FIGHTS

Put a bunch of chickens together and they will set up a dominance order by pecking at each other; the winner stays on the top. This sort of sociological dominance order is called the peck order. When chickens are crowded together in coops, such competitive fights occur more often and in a poultry farm, where crowding is usually the rule, about 25 per cent of the birds are lost in these fights. This is because if blood is drawn from a losing fowl—during a fight—the rest of the birds peck it to death.

Poultry farmers have one solution to the problem—mass disarmament. One third of the bird's upper beak is cut so that it cannot inflict fatal wounds. However, this debeaking also affects eating; a lot of chicken feed is lost due to the spillage while eating. So the problem is to get a method of preventing fights without causing any other losses.

Now scientists at the Virginia polytechnic Institute (VPI), USA, have found that if birds were fitted with red contact lenses, the fatal encounters would not occur. Not only that, a firm hired A. T. Leighton of VPI as consultant and he has already designed a lens. It is made of plastic, and rests over the inner of a hen's two eyelids. The inner eyelid keeps the eye moist and avoids the irritation caused by earlier designs.

I'M OLD-FASHIONED, I PREFER SPECS !!

NEW BONES FOR OLD

Scientists at the Harvard Medical School still don't know how, but they have managed to make patients grow bones of almost any size and shape, and, they hope, anywhere in the human body.

Replacement bones were grown in about 30 patients between the ages of one and 59. A six-year-old boy with a severely distorted skull had most of it removed and regrown into a normal shape.

Plastic surgeon John Muhiken and biochemist Julie Glowacki do not use grafts at all. Instead they use collagen, a glue-like protein extracted from bone. Collagen can be made into blocks, discs or paste which then serves as some kind of template. Somehow collagen stimulates surrounding cells to form bone and migrate into it and the patient himself grows the bone around the template!

EXOTIC AIR POLLUTANTS AT THE NORTH POLE...

No local factors pollute this atmosphere, yet two US groups and one Canadian group of air chemists have found aerosols in the Arctic air. In the spring and winter, pollutants cross more than 5,000 km to pollute the Arctic and produce a pervasive haze.

The early winter aerosols seem to come mainly from the central Soviet Union but as winter progresses West Europe is the main contributor and by spring the US has its turn. The longest routes take the particles between 5 and 10 days of travel and are longer than the 2,000 to 3,000 km pollutant pathways so far known. The pollutants are found only in the spring and winter because they are not washed out by the small precipitation. The aerosols will definitely heat up the Arctic but the undecided question is how much?

...AND IN THE TROPICS

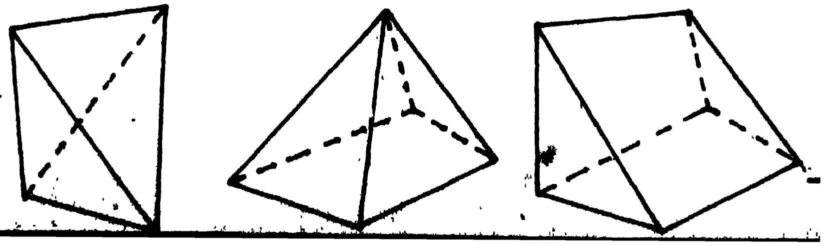
More than 1700 rainwater samples collected at nine places on the Hawaii islands show increasing acidity as we climb up, from a pH of 5.2 at sea level (pH below 5.6 is taken to characterise acid rain) to a pH of 4.3 at 2500 m. This is equal to the annual average pH of rainfall in northeast USA, the most industrialised part of USA. By contrast, the position is not as bad for the

WHEN THERE IS MORE THAN ONE CORRECT ANSWER

Can examiners be stumped by their own questions? Not impossible. Two 17-year olds in the US, David Lowen and Michael Galligan, convinced the designers of the Scholastic Aptitude Test (SAT) that two of their answers marked wrong were correct. Result: students in the US receiving a SAT will now get a copy of the questions, a list of correct answers and their own answer sheets.

Lowen's answer concerned pyramids. If two equal faces of two solids are placed flush together the number of faces of the composite solid is the total number of faces of the two pyramids less two. But what if some faces join up to form a single continuous one (see figure)? Apparently SAT designer had not thought about it, and marked Lowen's correct answer wrong.

Pyramids floor SAT examiners. In the two pyramids at left below, all the faces, except the square base of one, are equilateral triangles of the same size. Place them one upon another so that the shaded faces cover each other. You will get a solid with five faces, as shown at right below, instead of one with the expected seven (5+4−2)



LOOK! EARTH HAS BANDS LIKE JUPITER

relatively cleaner southern hemisphere at Samoa, an island in the South Pacific; the pH was 5.6, the anticipated value of uncontaminated rain.

From where does the acid come? Obviously, the first candidate are pollutants from the industrialised areas. In the proposed mechanism, they travel at a height of several kilometres, quite unlike the pollutants travelling to the Arctic. But like the Arctic pollutants they are also not washed out of the air for lack of contact with the ocean surface and precipitation. Later they subside towards the ocean surface. Researchers even suggest that in Hawaii, rainstorms may pluck them out of the troposphere and wash them down.

But a natural source cannot be ruled out completely. Biological processes in the ocean also produce sulphur compounds like dimethyl sulphide. This may oxidise to sulphuric acid to give acid rain.

WHO DISCOVERED CALCULUS?

Newton and Leibniz almost simultaneously discovered the calculus. They fought a fierce and bitter battle each claiming to be the first discoverer. Now W. Wieser (*Science* 212 875) preempts both of them.

Wieser reports that the calculus was discovered even earlier by an obscure but brilliant Austrian monk with an impossible name, Johan Jakob Tschurtschenthaler (1630-1670) from Thaur, a small village near Innsbruck. Johan, a farmer's son, ran away from home and took shelter in the Strams monastery. The monks quickly discovered his intellectual powers and educated him.

Johan went on to construct elaborate wind-driven waterworks, a famous clock and many other mechanical devices. He was also a skilled mathematician, though with a very practical mind, and invented a new method of triangulation for measuring mountain height with great precision. His manuscript on calculations, which contains all the ingredients of the calculus, can be dated to the year 1660 or 1661, a few years before either Leibniz or Newton arrived at their results. He might certainly have found many practical uses for the calculus had he not died untimely by drowning a few years later.

FUELLING ON THE MOVE

What would electric car fueling stations look like? Probably there won't be any special fuelling stations. If the US scientists' research proves feasible, roads will have fuelling stretches laid out at regular intervals. And all you have to do to recharge you automobile is to drive over it. To all appearances, a short 50 m track of road built by researchers at the Lawrence Livermore Laboratory, USA, looks like any other asphalt road. The road is an almost continuous recharging station which can deliver 100 kW of electric power to specially modified electric cars.

Recharging is the main problem with electric cars, especially on long and lonely stretches of road. The new electromagnetic roadway has thick, insulated aluminium current-carrying cables running through them. The cables set up a huge 10,000 gauss magnetic field. Special pick-up elements suspended from modified designs of the electric car soak up power from the inductive current.

Modified cars can run at 90 kilometres per hour and draw their power while on the move. The cost of building such roadways, it is estimated, would be Rs. 18 lakhs (US $ 220,000) to Rs. 30 lakhs (US $ 375,000) per kilometre.

WHY SATURN IS HOTTER THAN IT SHOULD BE

Saturn emits 2.5 to three times as much heat as it receives from the Sun. Where does the extra heat come from? The secret, it appears, lies in draining of helium from Saturn's upper atmosphere.

Saturn's atmosphere, like Jupiter's, is mainly made up of hydrogen and helium. Since helium is heavier than hydrogen, it has a tendency to sink downwards to planetary surface. And friction between descending helium droplets and surrounding hydrogen produces the excess heat. This view can be checked by seeing if there is any depletion of helium in Saturn's atmosphere compared to Jupiter's which has 90 per cent hydrogen and 10 per cent helium, the same as that in the Sun, the stars and in the universe as a whole.

Jupiter also emits excess heat—about 1.8 times the amount it receives from the Sun. But this is nicely accounted for. It is just what a planet of Jupiter's size, formed nearly 4.5 billions years ago, would be radiating as it cools off.

The excess heat of Saturn cannot be explained as due to the cooling off of the planet. To emit so much heat, Saturn would have to be younger—about two billion years old. The idea that Saturn formed later than Jupiter seems preposterous since it is contrary to our present understanding of the formation of the solar equator.

The scientists were in a fix because the previous ground based and Pioneer 11 observations could not show helium depletion. But the infrared instrument on board Voyager 1 spacecraft which flew past Saturn indicated helium abundance to be four per cent—just the estimated value if gravitational separation of the two elements, hydrogen and helium, had been taking place.

CAESAREAN DELIVERIES ARE BAD FOR THE MOTHER

Repeat caesareans are one of the four main medical reasons why the frequency of caesarean deliveries has jumped 300 per cent in the US over the past decade. Ninety nine per cent of women who have undergone one caesarean delivery have to undergo another in subsequent pregnancies. Abnormal labour, fetal distress and breech delivery, in which the fetus is delivered bottom first, are the other three reasons. But there are other non-medical reasons as well and many of the caesareans could be handled differently, according to the papers presented at the First International Symposium on Computers in Perinatal Medicine in Cleveland, USA.

Obstetricians, it emerges from a paper by Helen I. Maries, perform some caesarean sections (c-section) to avoid the mothers suing them for the delivery of a less than perfect baby. Yet, more malpractice suits are filed *for* c-sections rather than a failure to perform them. The second, and simple, reason is that c-sections earn obstetricians more money.

Calvin J. Hobel of the University of California presented a study showing that repeat caesareans may cost more and be less safe than normal vaginal deliveries. Hobel and colleagues compared cases of women who were undergoing repeat caesareans and those undergoing normal deliveries after undergoing one caesarean. They found a significantly higher risk of infections for the mothers undergoing repeat caesareans.

Of course caesarean deliveries cannot be dispensed with when obstetrical complications require it. But they need not be resorted to so often. The US National Institutes of Health task force on the subject reported last year that even abnormal labour should be corrected wherever possible rather than rushing in for the quick caesarean way out.

[illegible]

A few minutes before 11 pm on 9 July 1962, a 1.4 megaton hydrogen bomb exploded 400 km above Johnston Island in the North Pacific. In a tiny fraction of a second, street lights went out in Hawaii, burglar alarms started ringing, and circuit breakers in power lines snapped open. The culprit? A powerful electromagnetic pulse (EMP) wave, which is harmless to humans, set off by the nuclear explosion.

Multiply the above scenario for many cities; add more vulnerable microchips which have now replaced virtually all electronic equipment and without a single life being lost there would be a complete breakdown of communications and power circuits. This has become a nightmare to military and scientific circles in the US.

The EMP of energy is created when gamma rays from a high altitude nuclear blast knock off Compton electrons from the upper atmosphere. The electrons then are forced to turn around the fields lines of the Earth's magnetic field. This creates a powerful pulse which rapidly reaches its peak in a few nanoseconds and falls off. The trouble is that it peaks so fast that conventional protection devices like lightning arrestors are left far behind and the pulse surges through the equipment. For a device exploding 500 km high, the pulse would be 25 kV per metre strong all over the US!

Awareness of the problem dates back [illegible] had been done and the whole matter was kept quiet. Now it has broken out and a debate is raging in the US. Protecting equipment against the pulse, "hardening", it in military jargon, is a pretty expensive affair and still does not guarantee "survivability". Apparently the Soviet Union already knows about it and, some scientists and policy makers argue, are already taking steps against it. Military stratagists fear that in a pre-emptive strike, EMP would disrupt "command and control" operations of the US weapon system.

Satellite systems would be more reliable, "survivable", and so would be the optical fibre based communication systems. But even now, no one really knows how "survivable" a "hardened" system would be. What is more serious, as L. Basdekas, a safety engineer with the US Nuclear Regulatory Commission (NRC), points out is the possibility on meltdowns in nuclear reactors. A US government study had found it unlikely, but in view of the debate, the NRC has decided to take a second look.

The most difficult part of EMP regulation is that it affects outdated, inefficient first generation electronic equipment much less than the later generations of efficient, miniaturised, solid-state components. And yet, nuclear power and nuclear weapons have become accurate and efficient precisely because of the microchip revolution.

HOW FARES YOUR FVC!

Remember the days when you blew balloons as a child. Was blowing a balloon much easier for you then than it is today? If so, you perhaps will not live very long, according to a report in the *Journal of the American Medical Association*

Forced vital capacity (FVC) measures a person's ability to take a deep breath and forcefully exhale into a spirometer. According to William B. Kannel and colleagues at the Framington Heart Study in Massachusetts, USA, FVC is a measure of a person's overall "capacity for living". In addition, the investigators have discovered that hand-grip strength is one of the best correlates of FVC. Could gripping too thus be an index of physical fitness?

And you can't have your FVC intact for ever. FVC declines with age. And even with training you cannot regain much of it that is lost. In most cases, athletes have higher FVCs than others, The report also says, cigarette smoking accelerates the decline of FVC But when an addict quits the habit the rate of decline of FVC can again get back to normal.

Although women have smaller FVCs than men, their FVCs are better indicators of health than the men's, says the report. For instance, an inverse relationship between FVC and heart disease is striking in women—a relationship that is independent of age, obesity, smoking habits, and evidence of lung disease or chest deformity.

MAKING THE THIRD WORLD SMOKE

Most of us are familiar with the statutory warning printed on cigarette packets and their advertisements. The fact that smoking causes cancer and a host of other problems is well known only among the educated, especially in the developed world. The majority of people in the developing countries—mostly in African and Asia where no health education usually exists—still view smoking as a refreshing habit and one that symbolises success and virility as the advertisements invariably suggest.

In a recent issue of *USA Today*, Elizabeth M. Whelan and Margaret Sheridan who are, respectively, executive director and research associate with the American Council on Science and Health discuss the consequences of this third world attitude to cigarette smoking.

The fear of cancer, government concern over the cost of health care and regulated advertising, among other things, have together brought the demand for cigarettes to a standstill in the USA and other industrialised western nations. But, in many developing nations cigarette smoking is increasing at an alarming rate. According to a Food and Agriculture Organisation (FAO) estimate, tobacco consumption rose by only 4 per cent in North America during the last 10 years. During the same period, it rose by about 33 per cent in Africa and by 24 per cent in Latin America.

Whelan and Sheridan say the chief reasons for this is the American tobacco industry's marketing strategy. Faced with a threat of diminishing sales in their own land, cigarette manufacturers have identified the people of the third world as a vast, untapped market for their product. Happily for them, very often, even restrictions on advertising do not exist in most of these countries. And a more subtle, but no less important, industry effort has been undertaken to convince governments of the economic benefits from cigarette taxes. "In some cases, this persuasion has been enhanced by disreputable methods", say the authors.

Some statistics to confirm what Whelan and Sheridan have said may be got from a recent UN Conference on Trade and Development report entitled "The Marketing and Distribution of Tobacco". American cigarettes exported are probably much more carcinogenic and otherwise harmful than the same brands available at home. For instance, Kents sold in the Phillipines contain 33 mg of tar per cigarette as compared to 16.5 mg in the US The same goes for Kools: 32 mg as compared to 18 mg. The UN report concludes, "In addition to mass advertising, another component of world tobacco marketing is global corporate bribery, or the 'pay-off' complex involving million of dollars."

No wonder US exports shot up from an annual $650 million worth of tobacco products in 1974 to $2,150 million in 1979, setting the stage for smoking-related diseases on an epidemic scale on this side of the Earth.

"Buy our cigarettes now, get sick, then come back and buy our drugs!"

The latest Jaguar International, in service with the Indian Air Force, is an even more powerful version of the aircraft which has proved in service with the Royal Air Force in Britain and Germany, with L'Armée de l'Air in France and overseas, and with the air forces of Ecuador and Oman, that it provides the versatile, cost-effective weapon system essential to meet tactical defence requirements throughout the 1980s and 1990s.

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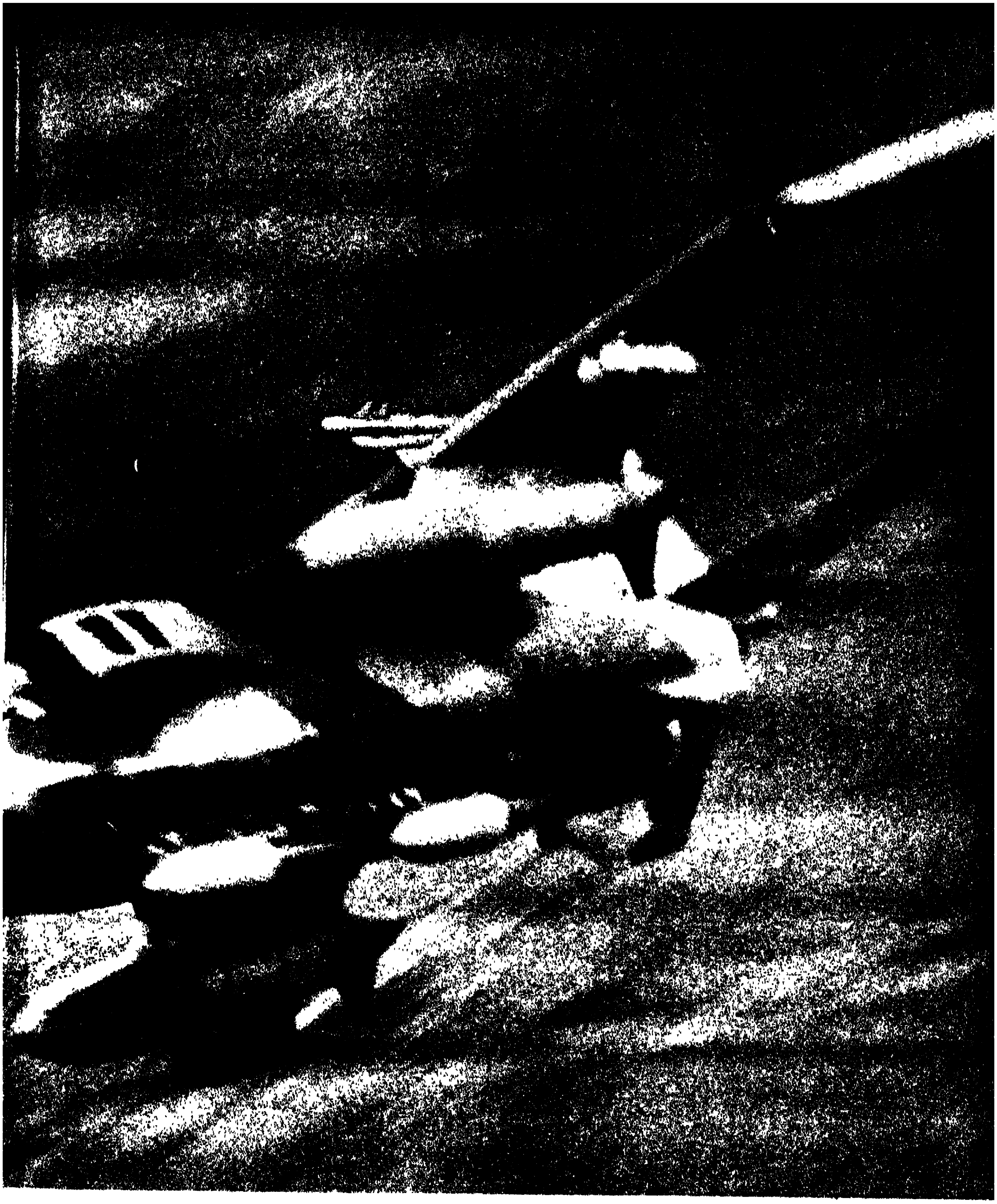
- it has the advanced systems design and structural qualities to penetrate sophisticated defences at high speed and low level in all weathers and to locate and attack the most difficult targets with consistent precision.



- it has the reliability and ease of maintainability to allow long periods of operation away from base facilities
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- it adds formidable air-combat, self-defence capability to the exceptional survival ability ensured by rugged structure, twin-engine configuration and duplicated systems.

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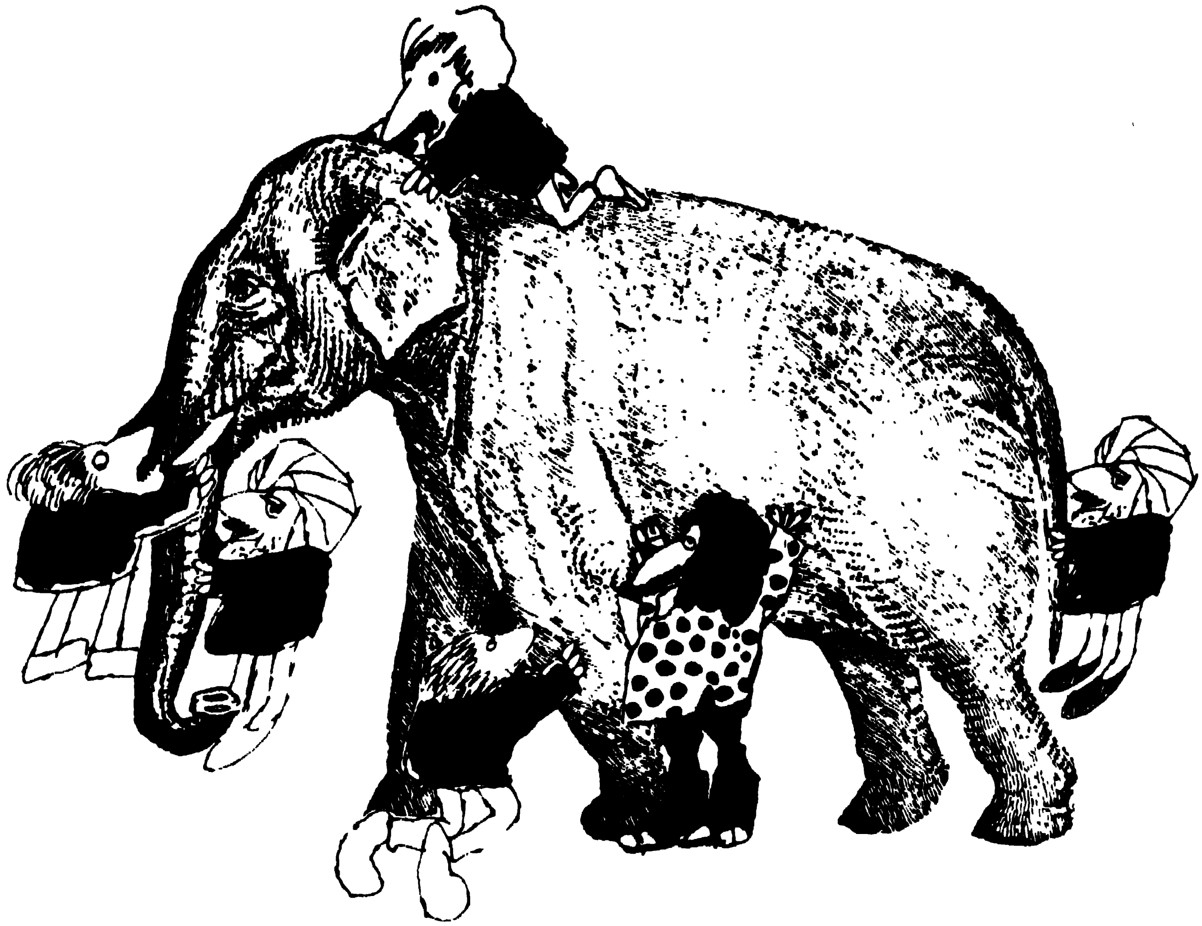

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Asteroids and comets near the Earth

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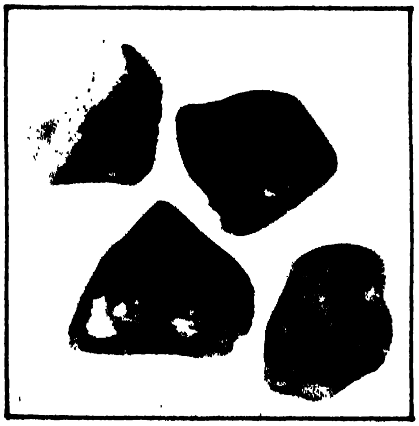
Tom Gehrels

Surveying asteroids and cometary cores may help us understand our own origins

School children looking for bits of meteorite that hit the Earth at Dhajala in Gujarat. Guided by scientists from the Physical Research Laboratory, Ahmedabad, the children were quick to recognise the extraterrestrial stones. The meteorite landed in the evening of 28 January 1976 accompanied by a loud noise and light effects. About 35 cm across, the object broke into bits while passing through the atmosphere

...With a little bit of an asteroid in hand



Bits of the Dhajala meteorite

SIXTY kilometres east of Flagstaff, Arizona, USA, lies a crater 1.5 km in diameter and 170 metres deep. It was caused by a nickel-iron asteroid about 22,000 years ago. About 25 metres in diameter, it came in from the north with a velocity of at least 15 km per second. The energy of this impact and explosion was equivalent to 1.3 × 10^7 tonnes of TNT (trinitro toluene), which is used as a standard unit for measuring explosive effects. Compare this with the 2 × 10^4 TNT equivalent of the nuclear bomb dropped at Hiroshima.

Fortunately, according to Eugene Shoemaker, of the Jet Propulsion Laboratory, Pasadena, USA, the chances of such an event occurring anywhere on the Earth is once in 10^3 years.

What are asteroids and where do they come from? It is believed that after the Sun was formed, it was surrounded by a cloud of particles. These particles met, fused and grew, and formed planetesimals which, in turn, by further aggregation formed the terrestrial planets and the cores of outer planets. Asteroids are leftover pieces of such planetesimals, with little modification other than those caused by mutual collisions. They represent the most primitive material from which the solar system was formed.

The story of asteroid's origins is in a way the story of the origins of the Earth and the solar system.

On a clear, dark night, have you seen the Milky Way, with thousands of stars and splotches of clouds between them? These clouds are composed of gas and dust particles from which new stars can form (SCIENCE TODAY, April 1981, p. 25). The density of these clouds, however, is too low—of the order of 10^{-20} gm cm^{-3}—to be able to form a star or a planet. But if there is a big increase in density, the self-gravitation can make the cloud collapse into a star.

The density increase may result from the shock front of the material sent flying out by a supernova. That supernovae were indeed involved in the formation of the solar system has become clear from the study of meteorites. A meteorite that fell in 1969 near the village Allende in Mexico has revealed abnormal compositions in its small, centimetre-sized inclusions which could have resulted only from an influx of supernovae material.

The Sun itself is the result of an accretion of dust particles as well as the gas of the interstellar clouds. Its composition—mostly hydrogen—is similar to that of the cosmic abundances of chemical elements. Closest to the Sun are the terrestrial planets—Mercury, Venus, the double-planet Earth-and-Moon and Mars. They consist mostly of heavy elements. Farther out, the cosmic abundances are dominant again in the planets Jupiter and Saturn, as also in the outer gaseous planets Uranus and Neptune. The outermost planet Pluto is a special body similar in composition to cometary nuclei and satellites of outer planets.

Most asteroids occupy a belt that

lies between the orbits of Mars and Jupiter and form a chemical transition region.

Special characteristics

About two hundred years ago, from a formula known as the Titius-Bode law of planetary distances, it was inferred that a planet was missing between Mars and Jupiter. Later, instead of one, many small planets, or planetesimals, were found (see box on p. 26). And now the yearly catalogue *Ephemerides of Minor Planets* issued by the Institute for Theoretical Astronomy in Leningrad lists 2,178 asteroids in its volume for 1981. It also gives the precise orbits and coordinates and the most favourable times for observing them.

Asteroids have elliptical, Kepler orbits around the Sun, mostly in the Main Asteroid Belt which lies just outside the orbit of Mars. These orbits observe the following laws: each orbit is an ellipse with the Sun at one focus; equal areas are swept out in equal times; and the square of the period is proportional to the cube of the distance from the Sun.

The largest asteroid in the main belt is about 1,000 km in diameter. The mass distribution of asteroids is such that there are a few large asteroids and increasingly more of the smaller ones; it is estimated that there are about 100,000 of them of one-km diameter. The frequency at which they collide with one another is about once in 10^6 years. The force of the collision and Jupiter's gravitational action help to spread the fragments through space.

The Earth-approachers

In the region near Earth, asteroids come in three types. They are called the Earth-approachers. The first type consists of asteroids from the main belt which have an extremely elliptic orbit. Their perihelion—the point on the orbit which is nearest to the Sun—is close to the Earth's orbit or even inside it and the aphelion—the point on the orbit farthest from the Sun—lies in the asteroid belt. The second consists of asteroids whose nearly circular orbits lie close to that of the Earth. The third type is made up of the nuclei of dead comets.

The second category was discovered just five years ago and at

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The Spacewatch Camera

THERE are several reasons why the Earth-approaching asteroids need to be discovered and studied to a much greater extent than is presently done. This can be done with a camera. We considered a photographic Schmidt Camera, but the efficiency of its photographic plates is too low to detect the small, fast-moving objects that make a trail on long exposure. Some preliminary surveying is underway using Schmidt-type photographic telescopes, especially at Palomar by Shoemaker. But the discoveries are slow to come. Only two or three asteroids are found each year. In Arizona we are therefore designing a special 1.8-metre aperture telescope, the Spacewatch Camera. This is being done together with Shoemaker who works on this programme at the Jet Propulsion Laboratory.

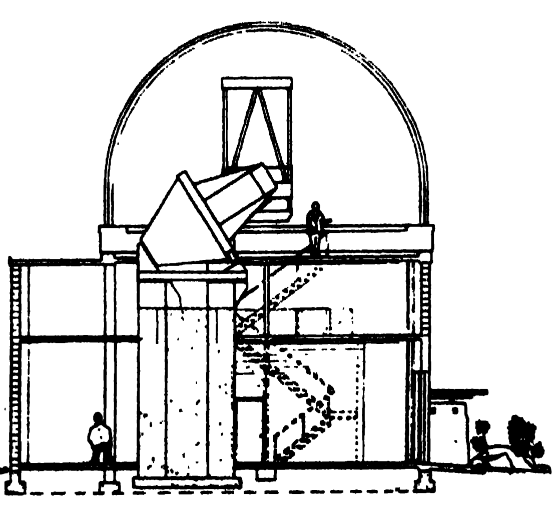
A 10-year task has been laid out to discover the estimated 1,500 Earth-approaching objects and to determine their orbital elements (semi-major axis, eccentricity and inclination with respect to the ecliptic plane), reflectivities and colours where possible. A detector called CCD (charge-coupled device) chip appears to be the appropriate panoramic detector. Our camera will have an array of 512 × 320 pixels that are semiconductor light-sensitive elements, silicon diodes, each of size 30 × 30 micrometres. The CCD will be mounted at the prime focus, F/2.2. The direction of the row of 512 pixels will be in the direction of scanning the sky, in right ascension.

Charge coupling means that, at a controllable rate, the charge is transferred from pixel to pixel along the row of 512, finally arriving at an output register. The rate of the charge transfer is set equal to the rate of the scan of the telescope on the sky. The output register reads each arriving charge from the 512 columns and the 320 rows.

All of this, adding up to 1.5×10^6 binary digits ("bits") per second, is stored in a computer. After a 5-minute scan, the telescope is reset and the same scan is entered, while the computer finds out which one of the stars did not occur at the same place on the two scans. These then were not stars but moving objects—asteroids or cometary cores that came close to the Earth.

The use of Spacewatch Camera can open new perspectives. It can help not only to avoid disastrous meteorite or asteroidal impacts on the Earth, but also to understand these fellow travellers in space better for an improved understanding of the origin of the solar system. Knowing their total population, orbits, sizes and types, we can infer the possible rates of collision with the Earth and Moon. Comparing these rates with the records of impact-cratering on the Earth and Moon, we can determine the relative order, in terms of mass and time, of the impact events. We could also study the origin and dynamical evolutions of asteroids and cometary cores, and investigate the connection between the meteorites and their parent bodies.

The three telescopes of the University of Arizona Observatories on Kitt Peak. The dome on the left is assigned to the future Spacewatch Camera



The 182-cm Spacewatch Camera sketched into its dome on Kitt Peak. The drives, in right ascension and declination, will be torque motors directly attached to the axles. The position control will be achieved through encoder outputs analysed by the electronic drive system computer

present only four such asteroids are known. They are called the Atens. It is surmised that they strayed away from the main belt and the gravitational effects of Mars and Earth fixed them in their present orbits. Some of them have not as yet been captured and they still move freely in space; their orbital speed and direction are more or less the same as that of the Earth.

So far, 40 Earth-approachers have been discovered. Based on the statistics of the discoveries and from their sizes, Eugene Shoemaker has estimated that their total population is of the order of 1,500 for objects larger than one-km in diameter. Even though their orbits may cross that of the Earth, the chance of a collision is very small.

For a collision to occur, the object and the Earth must be coincident: that is, they must be in the same part of the orbit. This may never occur. An example is the asteroid 1864 Daedalus discovered at Palomar Observatory, in 1971; it cannot get closer than 40 million km to the Earth—well outside the collision range. In the distant future, however, this may change. The orbits of the objects are unstable and greatly affected by the gravitation of Jupiter, Mars, Earth and even Venus.

What are asteroids made of? Determining the chemical composition of these objects is done best by obtaining samples from their surfaces and bringing them to our laboratories for detailed analysis, as was done for the Moon samples. A future space mission may indeed obtain such samples through unmanned, or even manned, missions. Even today, it is possible to obtain at least an indication of the chemical composition of these objects by remote sensing. A material that consists partially of carbon, for instance, is very dark and has little spectroscopic signature. A metallic object, on the other hand, reflects the sunlight better and the silicates even more strongly, with wide but clearly distinguishable and identifiable absorption bands.

The metallic objects are of special interest, in that they hold the possibility of mining of asteroids in future. In Sudbury, about 200 km northwest of Toronto, is a 58 km × 26 km crater. Originally, it must have been fairly round but, apparently, it has been squeezed into an elliptical form by plate tectonics. Some 1.7 × 10^9 years ago, it seems, an asteroid crashed here. Either it was a metallic asteroid or its impact caused a terrestrial metallic upwelling, the result has been a gigantic mining enterprise on the site. Apart from copper and some noble metals, over Rs. 4,000 million worth of nickel is mined from here every year.

A comet against the background of star-trails

This was, of course, an object that had already landed on Earth. But this does make one think of the far future of our children and grandchildren, in terms of resources in space. The supply, however, will be limited to not more than about 100 Earth-approaching asteroids, larger than one km in diameter, of metallic composition.

Whatever may be our objectives for the future, the objects must first be found. And this is what the Spacewatch Camera is expected to do (see box on p. 24).

Cometary cores

The other Earth-approachers are comets.

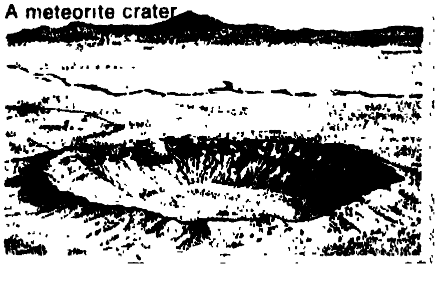
Our understanding of a comet depends upon our understanding of its nucleus. We have not yet succeeded in observing a bare cometary nucleus, since we cannot be certain that there was no dust cloud around it. However, there is a good theoretical model of cometary nuclei proposed by Fred Whipple around 1950. Comets come from outside the planetary system, from a region called the "Oort cloud", named after Astronomer Jan Oort. Comets, like the asteroids, were formed by the adhesion of interstellar dust grains. But comets were formed far away from the Sun, away from the source of heat. This meant it had water ice and other ices crystallising out in between the dust grains.

There is another difference. While an asteroidal rock can be as large as 1,000 km, the nuclei of the comets are smaller. The largest one is perhaps a hundred kilometres in diameter. This may be because the material density was low in the outer parts of the primordial solar nebula where comets formed.

When a comet comes close to the Sun, the lighter materials evaporate in forceful jets that take away some of the dust particles with them. When the Earth crosses a comet's tail, the dust particles in the tail entering the Earth's atmosphere appear to us as falling stars. They are the well-known meteor showers. These dust particles are about 30 micrometres across. Due to the friction of the atmosphere they heat up and burn out without landing on the Earth. This dust has been collected by high-flying aircraft and balloons, and interesting analyses have been made of the cosmic material that played a significant role in the formation of the solar system. We now know from Pioneers 10 and 11 that the interplanetary particles consist mostly of cometary grains rather than asteroid debris.

Sometimes we can telescopically observe the disintegration of a cometary nucleus. Comet Encke is an interesting example. It is an old comet that has lost its volatile material to such an extent that in less than 100 years from now all its ices and interior gases will have probably escaped. The dead rocky nuclei of comets however keep orbiting around the Sun and continue to approach the Earth occasionally. Unlike an asteroid which is made by vacuum welding, and sometimes by melting and differentiation processes, such a nucleus will be of a lighter structure because the gas jets have gouged through the mass and left it porous.

We try to distinguish the dead comets from the normal asteroids by using spectrophotometric and polarimetric techniques. So far there has been no definitive distinction, but at least three Earth-approachers, Icarus being one of them, appear to have exceptional colours at the large phase angle, the angle between the imaginary lines drawn from the asteroid's centre to the Sun and to the observer on Earth. This is an active


A meteorite crater

An example of a collision that was nearly disastrous in breaking up the original body—Mars' satellite Phobos. If the impacting mass had been appreciably larger, or the differential velocity higher, Phobos would have been broken into pieces. As it is, the surface now shows cracks stemming from the large crater named Stickney

field of study in planetary sciences at this time. We would like to understand better the fate of the short period comets in order to understand the formation mechanisms in various parts of the solar system. It will also help us to study the structure and composition of these most primitive objects for clues to the original interstellar material that formed the solar system.

The Tunguska event

The nucleus of a comet, or parts thereof, can come too close to the Earth and be captured. In 1908, a piece of comet Encke came into the Earth's atmosphere. It did not penetrate down to the surface, probably because of its loose structure and porosity. It did not, therefore, make a crater. But it caused a terrifying explosion kilometres high in the atmosphere. The energy of the explosion has been estimated at 10^7 tonnes of TNT.

The event occurred near Tunguska river in Siberia where even now the forest lies flattened over several kilometres. Of the porous cometary nucleus, one could find very little else than small glassy beads. On the other hand, when a meteorite or an asteroid enters the Earth's atmosphere, its body seems stronger and more compact. It penetrates the atmosphere and reaches the surface of the Earth.

Impact on the Moon

A meteor impact on the Moon may actually have been witnessed from Earth. The Canterbury monk Gervase has recorded the event (J. B. Hartung, *Lunar Science* 7 348) thus:

"In this year, on the Sunday before the Feast of St. John the Baptist (18 June 1178) after sunset when the Moon had first become visible a marvellous phenomenon was witnessed by some five or more men who were sitting there facing the Moon. Now there was a bright new Moon, and as usual in that phase its horns were tilted toward the east; and suddenly the upper horn split in two. From the midpoint of this division a flaming torch sprang up, spewing out, over a considerable distance, fire, hot coals, and sparks. Meanwhile the body of the Moon which was below writhed, as it were, in anxiety, and, to put it in the words of those who reported it to me and saw it with their own eyes, the Moon throbbed like a wounded snake. Afterwards it resumed its proper state. This phenomenon was repeated a dozen times or more, the flame assuming various twisting shapes at random and then returning to normal. Then after these transformations the Moon from horn to horn, that is along its whole length, took on a blackish appearance. The present writer was given this report by men who saw it with their own eyes, and are prepared to stake their honour on an oath that they have made no addition or falsification in the above narrative."

This observation by the Canterbury monks may be due to an impact event, though the last part of the description sounds more like that of a volcano or of a turbulence in the Earth's atmosphere. In any case, Hartung identifies a crater, called Giordano Bruno, in the proper place.

Asteroids

JOHANNES KEPLER was the first sky watcher who pointed out in 1596 in his *Mysterium Cosmographicum* that a planet was missing between the orbits of Mars and Jupiter. The idea found an echo 170 years later in the Titius-Bode law which formulated an expression for deriving the planetary distances from the Sun. Fifteen more years passed. William Herschel announced the discovery of a planet called Uranus which lay at a distance from the Sun that almost fitted the distance conjectured by the Titius-Bode law. And a serious hunt began for the missing planet.

The credit for discovering the "planet" goes to an Italian astronomer Guiseppe Piazzi, at Palermo, Sicily. On New Year's day in 1801, he observed a star-like object through a telescope. But on the following nights, he found that the object had moved with respect to the stars. This led him to speculate that he had discovered a comet. He could see this object for 41 days, after which it moved too close to the Sun and was lost in the glare. When informed of this discovery, the other astronomers checked their star-charts and found that this was indeed the missing planet they were looking for. Piazzi named this object Ceres after the patron goddess of Sicily.

Some time later, using the observational data, a brilliant young mathematician, Karl Friedrich Gauss, calculated the orbit of Ceres and predicted where it could be found again. And true enough, Ceres was sighted again on 7 December 1801. Within the next six years, three other "star-like" objects were discovered lying between 2.3 and 2.8 AU from the Sun, between the orbits of Mars and Jupiter.

Because they were much fainter than either Mars or Jupiter, all these objects were called minor planets. Being very small, they looked star-like even through the largest telescope and came to be called asteroids (from the Greek *Asteroides*). A few astronomers have been able to observe the large ones among them as extended objects.

By 1880 nearly 300 asteroids had been discovered. With the introduction of the photographic method of detection by Max Wolf of Heidelberg in 1891, a new era was ushered in and very soon hundreds of fainter asteroids were discovered.

While a comet is named after its discoverer and a meteorite is named after the place where it was found, an asteroid is given a permanent number after its discovery is confirmed. Followed by the number, it is given a name which may be chosen by its discoverer. The original plan was to name the asteroids after female mythological characters. For example, the first four, which are also the biggest ones, are named 1 Ceres, 2 Pallas, 3 Juno and 4 Vesta. But as the numbers burgeoned, this system was thrown out of gear. Now the discoverers have started naming them after their spouses, lovers, friends, pets, etc.

Though about 93 per cent of the asteroids lie in what is called the main belt between 2.2 and 3.2 AU (between the orbits of Mars and Jupiter), and have elliptical orbits of low eccentricities, there are others which have highly elliptical orbits.

The highly eccentric orbit of Hidalgo stretches from the inner edge of the main belt to a distance beyond Saturn. Chiron discovered by Charles Kowal in 1977 is the only object whose perihelion is a little inside the Saturn's orbit and aphelion close to the orbit of Uranus. There is a group of asteroits called Trojans (Hektor is one of them) which shares the orbit

The largest asteroids that cross the Earth's orbit are about 10 km in diameter. The chance of such an asteroid hitting the Earth is estimated at once in 10^8 years. This time scale is similar to that of geological periods named after sudden changes in the Earth's fauna, namely the Paleozoic-Mesozoic and the Cretaceous-Tertiary Extinctions. The latter has recently been interpreted by Luis Alvarez and colleagues as being due to the impact of an asteroid of about 8 km in diameter (SCIENCE TODAY, July 1980, p. 27).

The impact which occurred 65 million years ago resulted in a thick dust cloud surrounding the whole Earth. Dust clouds have enveloped the Earth following the Krakatoa and other volcanic eruptions, but this particular cloud was so thick and

Table 1: Representative asteroids

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Type
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	1.1	.18	19	[illegible]	[illegible]
[illegible]	Geographos	[illegible]	1.7	[illegible]	13	[illegible]	[illegible]
1221	Amor	1.1	2.8	.44	12	1	[illegible]
434	Hungaria	1.8	2.1	.07	25	12	[illegible]
1	Ceres	2.6	3.0	.08	11	1025	C
109	[illegible]	3.0	3.4	.07	4	79	[illegible]
153	Hilda	3.4	4.6	.15	8	119	[illegible]
279	Thule	4.1	4.4	.03	2	72	[illegible]
624	Hektor	5.0	5.3	.03	18	150 x 300	U
944	Hidalgo	2.0	9.7	.66	42	29	D
2060	Chiron	8.5	18.9	0.38	7	200?	?

*1 Astronomical Unit is the mean distance of the Earth from the Sun.

For the elliptical orbit, the distance closest to the Sun (perihelion) and the largest one (aphelion), the eccentricity, and the inclination of the orbital plane to the plane of the ecliptic are given, as well as the diameter of the asteroid. From colours and reflectivity it is possible to obtain some indication of the composition the types are indicated with the letters S for silicaceous, C carbonaceous, M metallic, D dark and red, and U for unclassified

of Jupiter, some preceding it, the others following it.

Sometimes asteroids occult stars. Occultations of stars by Herculina and Melpomene in 1978 had blackout patterns which suggested the presence of a companion.

Nature of asteroids

A lot of physical information about asteroids can be inferred from analyses of spectra of reflected sunlight and radiation emitted from the asteroidal surface. The magnitude of an asteroid observed for an extended period can be plotted as a function of time. Such a plot is called the light-curve of the asteroid. Analyses of amplitudes (peak-to-peak values) of such curves suggest that asteroids are irregularly shaped The spin rates of asteroids can be deduced from the light-curve period. Though the average rate of rotation of asteroids is about 8 hours, the shortest period found is about two and a half hours and the largest period, 85 hours.

To know the size of asteroids is of prime importance for an understanding of their reflectivity and thereby their surface composition. Indirect methods, such as radiometry and photometry, are yielding the first results. The three of the largest asteroids, Ceres, Pallas and Vesta are, respectively, about 1025, 593 and 555 km across.

The mass is determined from the close encounter an asteroid may have with another, but such opportunities are rare. The total mass of the main belt asteroids appears to be about 0.0005 times the mass of the Sun, or two-and-a-half times the mass of Ceres, the largest of them.

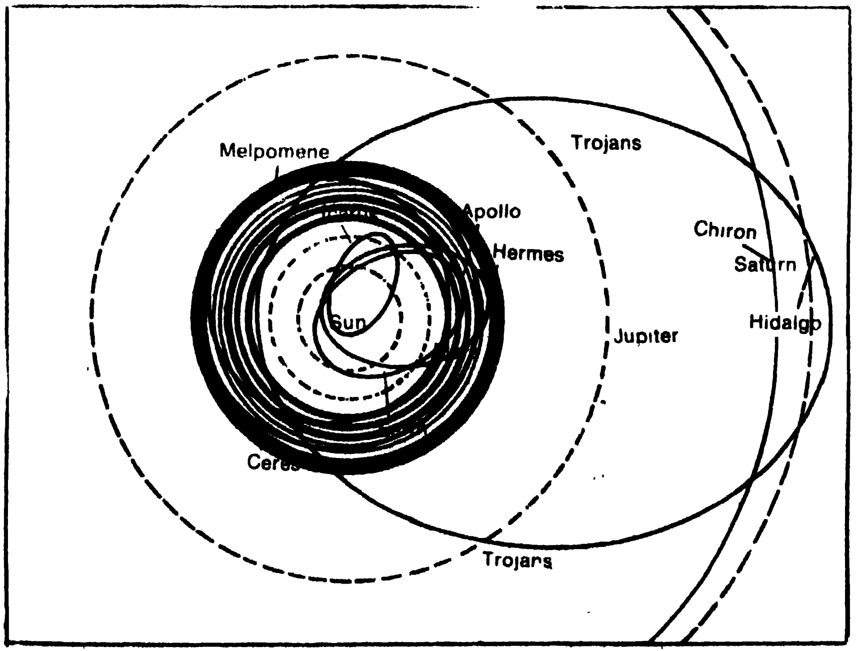
Asteroids whose spectra have been studied can be divided into three broad groups: (1) the very low reflectivity group with almost flat spectra, termed as C-type, (2) the moderate reflectivity group with curving, reddish sloping spectra, termed as S-type, and (3) a very small M-type, having moderate reflectivities and straight, slightly reddish, spectra.

When matched against the spectra of terrestrial rocks and meteorites, asteroidal spectra can be interpreted as C-type, perhaps corresponding to carbonaceous chondrites; S-type, perhaps stony-irons; and the the metal enriched M-types. The inner belt asteroids tend to be S-type.

Asteroids do not live calm and serene lives They are bombarded continuously by cosmic ray particles, solar wind particles and micro-meteorites. These leave traces of damage in the form of particle tracks, gas implantation and micro-craters. In addition, major craters are formed due to collisions with other asteroids. Some of these craters are deep enough to fracture asteroids and still larger impact craters may even break them apart. Some of the fragments might even become satellites of the parent body.

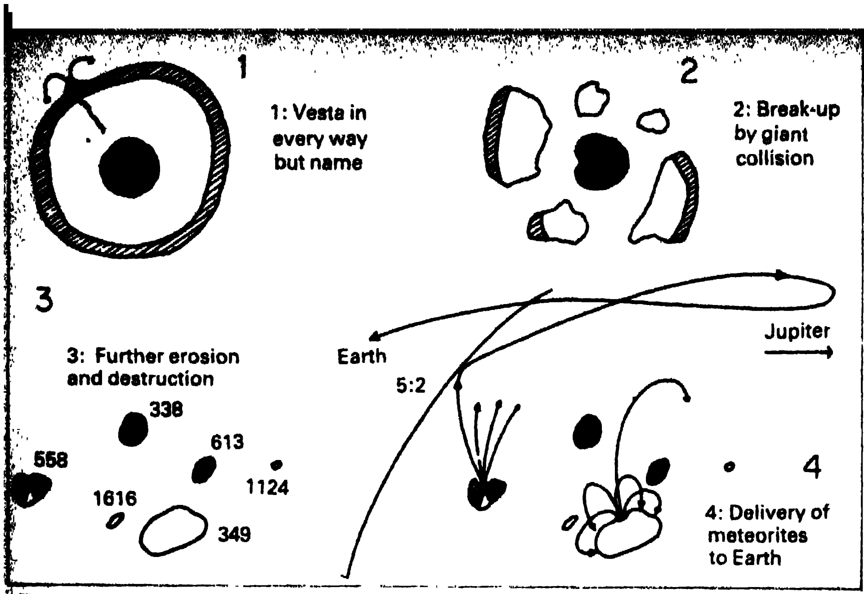
The unrelenting force of gravity governs the orbits of asteroids, but collisions and mutual perturbations, and gravitational perturbations due to a planet, can change the orbit of an asteroid so that it may cross the orbit of a planet. In the process such an asteroid may become a planet approacher, or may even fall down on a planet as a meteorite.

JYOTI NEVATIA



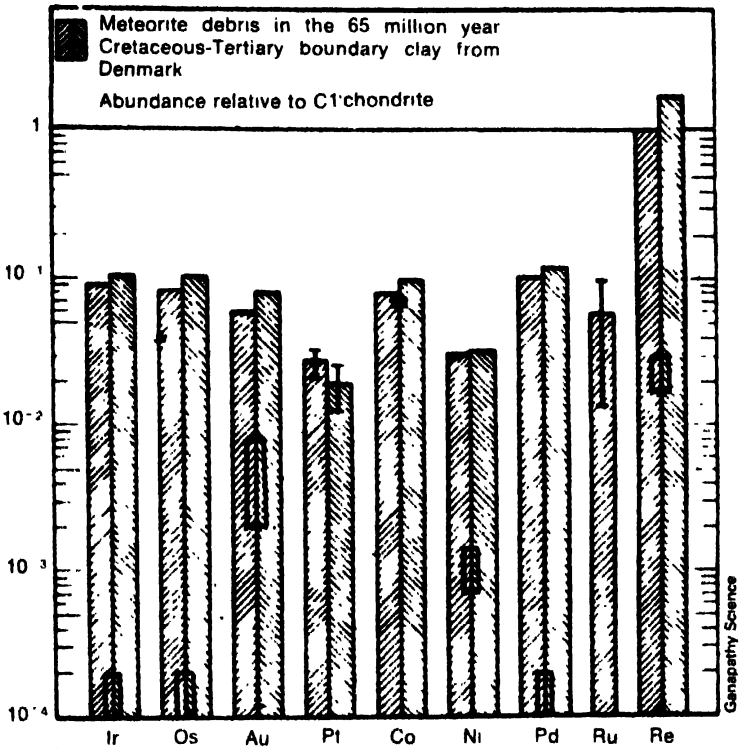
Some representative asteroid orbits Though most of the asteroids orbit between Mars and Jupiter, a few swing past the planets

Dr. Nevatia is on the editorial staff of SCIENCE TODAY


1
1: Vesta in every way but name
2
2: Break-up by giant collision
3
3: Further erosion and destruction
338
613
558
1124
1616
349
Earth
5:2
Jupiter
4
4: Delivery of meteorites to Earth

This picture shows two phenomena, namely, how meteorites of different compositions may have originated—1, 2 and 3— and how the delivery of meteorites to the Earth may have come about—4.

(1) Heat generation, by radioactivity or other processes, melted the original planetesimals. Heavier materials, given in black, settled gravitationally towards the centre The rocky material, left blank in the figure, formed on the outside of the metallic core The lightest carbonaceous material, etched in the figure, floated towards the surface. (2) After solidification and then a breakup by collision, there are asteroids of various compositions (3) After further collision we can recognise individual asteroids, indicated by their numbers in the Leningrad catalogue, of various compositions: the black ones indicate metallic types, the blank ones are silicaceous, while asteroid 558 is complex and also has some carbonaceous material. (4) The period ratio at this distance from the Sun is 5·2, which means that there are exactly five orbital revolutions of the asteroids at this distance from the Sun for two periods for Jupiter This gives a resonance effect that changes the orbits of the objects to such an extent that they may cross the orbits of planets Mars, Earth, or even Venus (Figure made by C. R. Chapman for p. 52 of the book, *Asteroids*)



The abundances of iridium, osmium, gold, platinum, cobalt, nickel, palladium, ruthenium and rhenium are given with respect to those of a carbonaceous chondrite meteorite. The average, other than the results for rhenium, gives about 7 per cent relative to the meteorite. If one takes the mean thickness of the clay layer all over the Earth at 1.5 cm, 7 per cent being due to the asteroid, assuming that the density of the asteroid is about the same as that of the Earth's mantle, then the diameter of the asteroid is deduced to be nearly 10 km

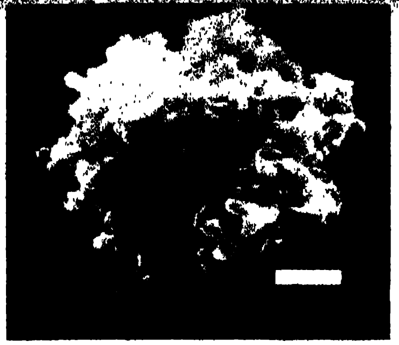
dense that it blocked out sunshine for five years or more, stopping the growth of green grasses and leaves, and the atmospheric circulation that brings the rains. Dinosaurs and various other animal species that depended on green fodder died out, so did other organisms that depended on sunlight. No land vertebrates larger than about 50 kg seem to have survived the Cretaceous-Tertiary Extinction although, later, bigger animals such as the rhinoceros and the elephant did evolve.

The dust which settled down in a 1-to-2 cm thick layer can be distinctly recognised and has been studied in sediments from Denmark, Italy, Spain and New Zealand. The samples have a meteoritic composition of the noble metals such as iridium. Since, during its formative period when the Earth was still partly-molten, these heavy elements settled down towards the centre, the Earth's mantle is deficient in them as compared to their abundances in meteorites.

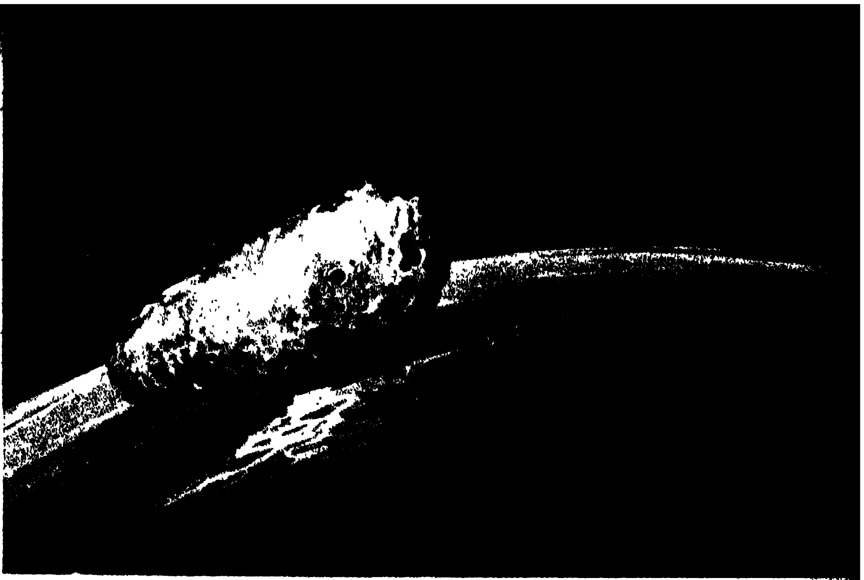
There are still a few large craters recognisable on the Earth, especially when seen from spacecraft like LANDSAT. But none of them seems to belong to the appropriate age to be identified as the crater responsible for the Cretaceous-Tertiary Extinction. However, Whipple (personal communication 1980) points out that even the oldest rocks of Iceland are of early Tertiary age. In other words, Iceland did not exist in the Cretaceous period. If an asteroid hit the place where Iceland is, it found a thin crust, only a few kilometres deep. This is a location near the oceanic ridge caused by plate tectonics where at that time the European and North American continents began to drift apart.

The 8-km asteroid can be estimated to have made a crater of about 200 km in diameter, a size comparable to that of Iceland. It also must have penetrated several kilometres and made an opening right into the more liquid part of the Earth's interior, thereby creating the large Icelandic volcanoes. There is some support for this idea, in that the iridium anomaly in the Cretaceous-Tertiary clay layer is stronger in Denmark, which is closer to Iceland, than at other places. But further studies are needed to confirm the unique position of Iceland, in geological time and place, with respect to the Cretaceous-Tertiary Extinction.

What is the chance of such an event occurring again anywhere on the Earth? No accurate estimates are possible until the Spacewatch Camera has become functional. This camera will actually observe and



An interplanetary dust particle collected and photographed by Don Brownlee. The scale bar indicates one μm



Artist's concept of an Earth-approaching asteroid

obtain the best possible statistics of the near-Earth objects. The impact rates obtained by it can then be compared with those estimated in classical papers by Ernst Öpik and others. After this, it will be possible, much more precisely than before, to date the relative order of the impact events on the Earth and, with the help of crater counting on various parts of the Moon, to study the various ages of these impact regions.

Information on asteroidal impacts have a profound implication for our own origins too. What if the dinosaurs and other large animals had not been wiped out? Is it not conceivable that in further evolution one of their types might have won out in the evolutionary race of the survival of the fittest? The new forms might then have become the predominant species, eliminating our own primate forefathers. In due time they would have evolved additional brains and eventually they would have become the dominant "people" of the Earth. This line of reasoning helps us to visualise that on other planets, elsewhere in the universe, the intelligent beings will probably look very different from what we do. So much chance and circumstance appears to be involved in these evolutions! The planets of other stars also undoubtedly have been, and are being, bombarred by the planetesimal debris left over after the formation of their system of stars and planets.

Collision can be averted

In any case, we should be, and can easily be, more intelligent than the dinosaurs were: we can take precautions against our own extinction by asteroid impact. In fact, our demise by nuclear warfare and its fall-out may be more difficult to avoid than the impact of another large asteroid.

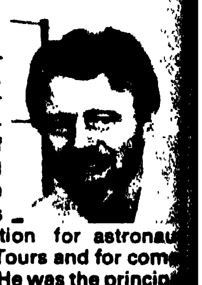
The Spacewatch Camera should be in operation by 1985. By 1995, it will have catalogued the large asteroids that can be Earth impactors. When a newly computed orbit indicates that a collision with the Earth is probable, it seems feasible to modify its orbit and avoid the impact. Even a small angular change in the orbit of the asteroid can bring about a large separation after a long interval of time so as to avoid any collision. For instance, those finely-targeted spacecraft, after a flyby of Jupiter, needed only weak jets of the hydrazine gas just for a few minutes to veer it away to one side of Saturn or the other. The propulsion provides a small angular change, which then operates over several months or years. A change of only a fraction of a metre per second in the velocity of the asteroid can steer it away from a head-on collision, provided the change is made years before the expected collision. Such a change can be accomplished with an explosion on the surface of the asteroid. It has been estimated that 10^4 tonnes of TNT are enough to deflect a one-km asteroid, even shortly before an expected collision with the Earth. By 1995, it will be possible for the Space Shuttle programme to deliver a forceful device onto the surface of an Earth approaching asteroid.

We should not get alarmed there fore over the possibilities of a majo asteroidal impact causing glob harm. A classical example of a unnecessary panic occurred in th year 1773 in France when a paper b de la Lande was misunderstood t predict the impact of a comet on 2 or 21 May of that year. My lecture i New Delhi on 5 August 1980 too wa misreported in the newspapers o India. Asteroid 1620 Geographos, was reported to have said, was to h the Earth in 1994. The year was soo updated to 1982 by another eage reporter. My denial was harder to g published.

There is no asteroid predicted t collide with the Earth in the foresee able future.

Table 2: Approximate statistics for Earth-approaching objects

Diameter (km)	No. of objects	Impact probability (once per number of years)	Impact energy (tonnes TNT)
10	10	10^8	10^{14}
1	1,000	10^6	10^{11}
0.1	100,000	10^4	10^8



Born in the Netherlands and now a US citizen, 56-year old Tom Gehrels is Professor at the Lunar and Planetary Laboratory, University of Arizona, USA. He served as consultant to the National Aeronautics and Space Administration for astrona training for the Grand Tours and for com and asteroid missions. He was the princip investigator on the Pioneer 10 and 11 mi sions and received the NASA medal for e ceptional scientific achievement in 1974. H established the IAU (International Astron mical Union) photometric systems for t asteroids. He has edited several books, i cluding *Protostars and Planets, Asteroi* *Jupiter*; now he is preparing a book *Saturn*.

Zooplankton

These drifting creatures are the backbone of the fishing industry

S. S. Bhattacharya

IN the home of the sharks, octopuses, seasnakes, dolphins, giant squids, mighty whales and a whole lot of exotic animals also live the not so impressive but extremely important plankton. Most plankton are free floating organisms which go where the current takes them. The name coined by German biologist Victor Hensen in 1887 came from the Greek *planktos*, which means "made to wander". But now it turns out that they are no mere flotsams; many animals belonging to this group can swim quite effectively and travel hundreds of metres everyday. Found in three forms, animal plankton are called the zooplankton; plant plankton, the phytoplankton; and the bacteria plankton, the bacterioplankton. Zooplankton is, in fact, a collective term that may include any animal belonging to any group which can float or swim feebly.

A study of the zooplankton is important because they provide the essential back up that sustains the world's fisheries. Many pelagic fishes and those at the early stages of development from several species, including the bottom-dwelling demersel fishes, feed on the zooplankton. The eggs and the larvae of almost all the fishes are planktonic. And some of the large-sized zooplankton such as krills themselves form a fishery.

Fortunately, the world's oceans abound in these planktonic organisms. If each cubic metre of sea water could contain up to 4,000 animals in the size range of 0.25 mm to 5 mm, all the seas together can accommodate 4,173,281,000 × 4,000 animals. This can, of course, never happen since major portions of the world's oceans are "biological deserts". Moreover, a vast number of phytoplankton and other animals also occupy the seas. But despite this, the total quantity of zooplankton produced in the ocean is enormous.

Although the great world of plankton was discovered no more than a century ago, one of the earliest references to planktonic organisms was made by Pytheas in the fourth century BC. The whalers knew them as indicators of a good whale catch, just as the fishermen knew that the phenomena of "red water", or "red tide", and "sliming" suggested hampered fishing. But because most plankton are very small—in many cases they are indeed microscopic—and it is not possible to catch them with ordinary nets, not much could be known about them. The breakthrough came in 1665 with Robert Hooke inventing a compound microscope. For, soon after, in 1667 the famous Dutch microscopist A. Von Leuwenhock noticed these minute organisms in samples of sea and lake water.

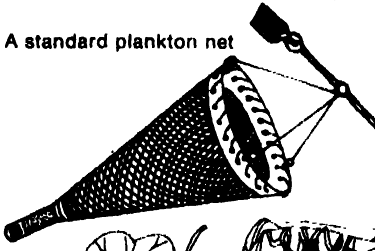
Table 1

Size of aperture of mesh of plankton net prepared from standard bolting silk

Silk No.	Meshes per inch	Size of aperture (mm)	
0000	18	1.364	
000	23	1.024	Macro plankton
00	29	0.752	
0	38	0.569	
1	48	0.417	
5	66	0.282	Micro plankton
10	109	0.158	
15	150	0.094	
20	173	0.076	Nano plankton
25	200	0.064	

Plankton can also be classified according to mesh size of the net they can be caught with. 1 inch = 2.5 cm.

A standard plankton net

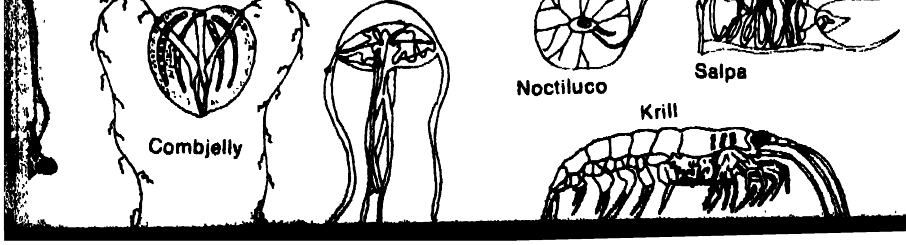


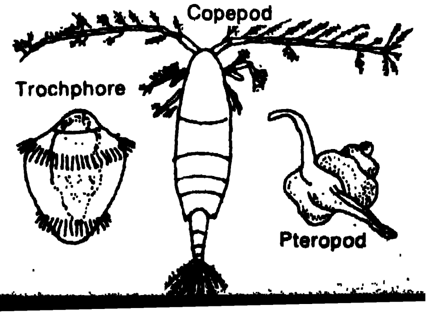
Things began to move faster after that. In 1828, an amateur naturalist and army surgeon J. Vaugham Thomson designed a very simple device he called the tow-net. Made up of a small conical bag of fine silk or muslin cloth or of nylon (now), it had a little jar at its end to hold the plankton. With this, Thomson did manage to trap some plankton. Using this net, the German biologist Johannes Muller was the first to study these organisms in 1844. His findings opened a new era and a vast field of research, so much so that it became the starting point of a new subject called planktology.

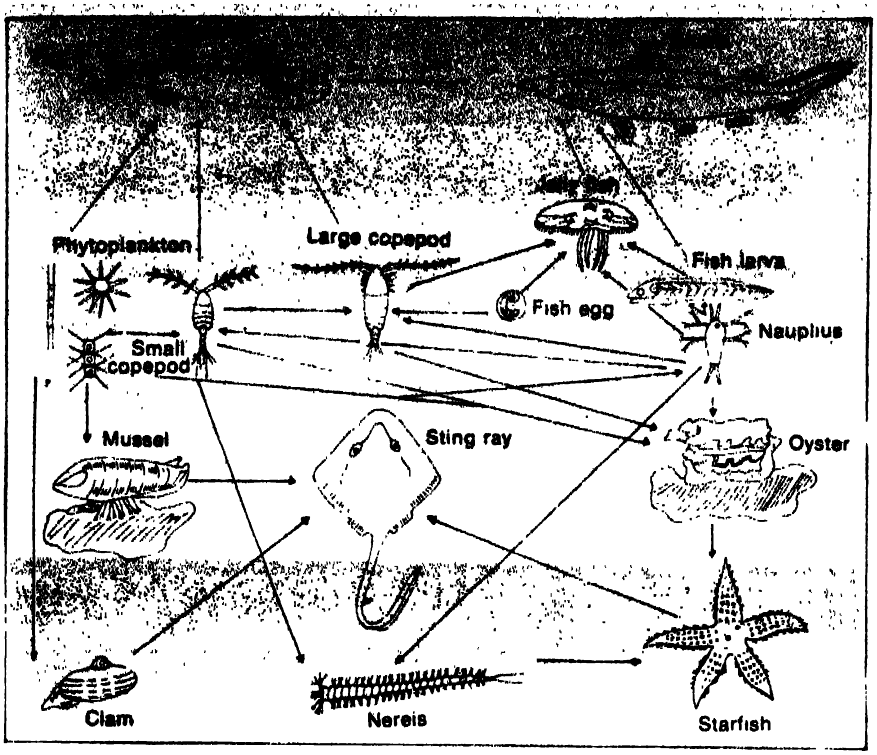
Its importance, however, was still not realised fully and the progress remained slow. Later, as the significance of plankton in marine life came to be better understood, many scientists plunged into the new discipline. There were a whole host of questions to be answered: Where and up to what depth are these organisms found? How many of them occur in a given region of the sea? What factors control their production? Which animals feed on them? What role do they play in the marine ecosystem, specially in the transfer of energy? To some, the answers came easily though somewhat slowly. To others, there are yet no answers.

For convenience, planktologists divide the zooplankton into three separate groups depending on their size or morphology, the duration of their lifecycle in the deep ocean, and their habitat or ecology.

As regards size, different planktologists have used different parameters, some even the size of the mesh of the net used to collect them (Table 1). But, recently, attempts have been made to be more specific. Thus, (1) megaplankton are animals measuring more than 2,000 microns (2 mm)—this group includes comb-jellies, jelly-fishes, krills, etc; (2) microplankton range from 200 to 2,000 microns and consist of copepods, pteropods, etc; (3) microplankton measure between 20 and 200 microns—this group consists of foraminifera, radiolarians, ciliates, etc; (4) nanoplankton range from 2 to 20 microns and consist of flagellates; and (5) ultrananoplankton which are very minute organisms below 2 microns—like bacteria.







A generalised diagram of marine food web in Indian waters. The food network may be simple and chain-like or a complex web-like structure. Some animals can be easily classified as herbivorous or carnivorous. But many animals are herbivorous at one stage of their life and carnivorous at another. Moreover, each animal has many food choices and one organism may be eaten by several species of animals

Now, depending on the duration of their lifecycles in the surface waters (pelagic state), zooplankton are seen to form two groups: meroplankton or temporary plankton, and holoplankton or permanent plankton. The meroplankton are organisms which are planktonic during a part of their lifecycle, such as eggs and larvae of fish, turtle, starfish, corals, clams, oysters, sponges, etc. Their occurrence depends on the spawning habits of the parent animals and, therefore, is seasonal. The holoplankton are planktonic throughout their life.

Zooplankton occur both in the coastal waters and in the open oceans. The neritic (or coastal) zooplankton can tolerate low salinity and high temperatures. The copepods—crustaceans—such as *Acartia* and *Pseudodiaptemus*, the mysids, certain jellyfishes like *Aurelia*, and larvae of animals. crustaceans, etc are all neritic. The oceanic zooplankton occur at some distance from the coast and can be found anywhere from surface levels to profound depths. These organisms cannot tolerate low salinity. Oceanic zooplankton can also be grouped according to the depth zone in which they occur: (1) epipelagic: those found between the surface and a depth up to 150 m; (2) mesopelagic: those found between 150 and 1,000 m; (3) bathypelagic: the ones found in the deep seas between 1,000 to 4,000 m; and (4) alyssopelagic: those occurring almost at the sea bottom between 4,000 and 6,000 m.

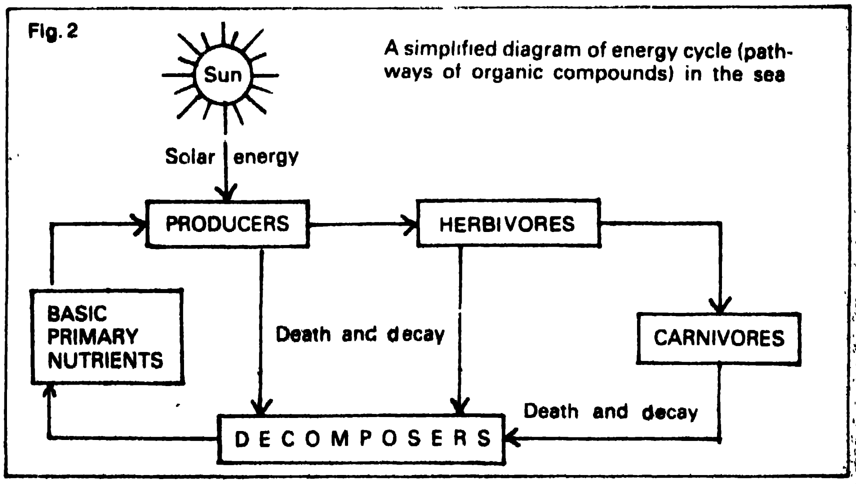
Nutritional requirements of various organisms have given rise to an interesting nexus of relationships within the ecosystem that constitutes the sea. It has taken the form of so many 'producers' and 'consumers' connected by various food chains. On the nutritive or trophic level, the ecosystem consists of autotrophic and heterotrophic components; trophic pertains to nourishment. The autotrophic component is self-nourishing and is also called the producer. It builds complex substances from simple inorganic substances using the Sun's energy. The heterotrophic component, which is the consumer, uses the complex product of the autotrophs and decomposes them into simple substances.

What really happens in the seas is that food energy from the producers is transferred through a series of organisms by a repeated process of eating and being eaten to form a food chain. The various food chains are in turn inter-linked with one another in characteristic patterns, called food webs (Fig. 1). The system comprises living and non-living components; the living components interact with the physical environment and produce a distinct trophic structure (feeding level), biotic diversity (variations of organisms) and material cycles (cycles of organic and inorganic materials).

A marine community is designated littoral (intertidal), neritic (inshore), or oceanic (open sea), depending on which section of the ocean it resides in. All the fundamental processes mentioned above, however, must go on within each community. Here, the autotrophs are the phytoplankton, though some other particulate organic nutrient materials have also been found recently in the sea whose source are not the autotrophs (Fig. 2). They come, apparently, from the surrounding areas.

The heterotrophs, the consumers, are also divided into different categories: primary consumers—the herbivores which feed on green plants; secondary consumers—the carnivores, feeding on primary consumers; and tertiary consumers—of different grades, depending on the size of the animal consumed (Fig 3 p 35). The microconsumers or decomposers are chiefly bacteria and fungi which break down the complex substance of dead animals and plants to derive energy from them, and, in the process, they release basic plant nutrients which become available to producers for their photosynthetic activity. At each transfer of food

Fig. 2



A simplified diagram of energy cycle (pathways of organic compounds) in the sea energy a large portion of the energy—about 80 to 90 per cent—is lost as heat.

The dissolved organic matter in the ocean is one of the largest reserves of organic carbon in the world. According to recent estimates the amount of organic carbon fixed annually by phytoplankton through photosynthesis in the sea is 1.9 to 2.3 × 10^{10} tonnes. The amount of zooplankton that might thrive on the fixed carbon depends on various factors associated with material transfer to the higher trophic level.

According to D. L. Alverson, the amount of first stage carnivores—animals that live on zooplankton—may exceed 2.3 × 10^{9} tonnes per year. In the Arabian sea alone the total tertiary level production for the two monsoon seasons is estimated to be about 62 million tonnes. The figure for tertiary production can give us an idea of how much of the secondary and primary consumers, that is the zooplankton, must be produced in the Arabian sea alone.

It may be interesting at this point to consider the estimate of the relative mean weights of phytoplankton, zooplankton and the fishes in the English channel. Its annual production as biomass was found to be 2.9 g pelagic fish, 1.9 g demersel (bottom dwelling) fish, 275 g zooplankton and 730 to 910 g phytoplankton, where g represents grams of biomass under one cubic metre of water. Another interesting example of the enormous amount of zooplankton that is produced in the ocean is the Anatarctic

Pollution and zooplankton

SINCE plankton are the backbone of our marine foods, it is important to know the effects of petroleum and other hydrocarbons (compounds of carbon with hydrogen alone), heavy metals, pesticides various chemicals, radioactive waste and heat on them and consequently on other organisms on the higher trophic levels. Plankton have been exposed to small quantities of petroleum hydrocarbons released from seeps in the ocean floor, heavy metals and radiation from the beginning of the geological time. However, it is likely that more and more of these compounds will continue to be released into the sea and, therefore, it is of interest fo find out what might happen to them when exposed to the additional quanitites of the various pollutants.

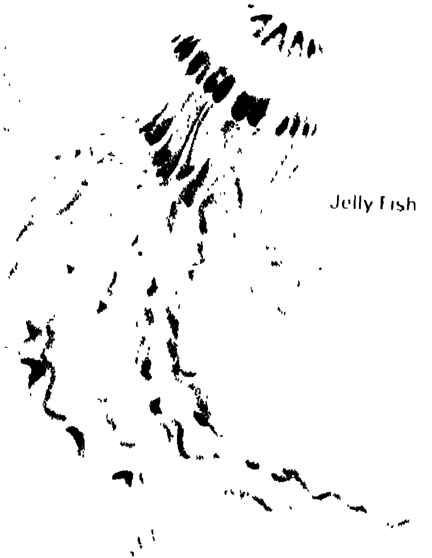
Hydrocarbons are constantly released into the sea through various processes such as accidental oil spillage due to offshore drilling, transport of crude oil, submarine seeps and as metabolic products of organisms. Near the coast, industrial oil discharges and sewage may also contribute substantial amounts of hydrocarbons. The total oil pollution in the oceans from various sources has been estimated to be about 6 million tonnes per year.

Hydrocarbon levels vary considerably with different areas and seasons. A comparatively high level of crude oil or total hydrocarbon is associated with the surface layers as well as from deep waters in the areas of offshore drilling activities and along the tanker shipping routes. Crude oil as high as 1.40 to 10.98 milligrams per litre has been found in the Adriatic sea off Italy. In certain harbours, for example Goteborg in Sweden, the concentration of total hydrocarbons has been found to be as high as 50 to 710 milligrams per litre.

Crude oil contains several hundred hydrocarbons and its composition varies from place to place. It also contains some sulphur and oxygen. How do these hydrocarbons enter into the body of zooplankton and move up to the higher trophic level. The hydrocarbons accumulate mainly in three ways: (1) from phytoplankton diets, (2) from assimilation of particulate diets, and (3) by the direct uptake from sea water. Exactly how much phytoplankton are contaminated with petroleum hydrocarbons is yet to be determined. However, it is certain that the hydrocarbons produced by the marine planktonic organisms are few compared to those contained in the crude oil. The hydrocarbons of exogenous origin in them must, therefore, be due to oil pollution.

In experimental studies, certain water-soluble hydrocarbons of fuel oil, such as WSF of No. 2 fuel oil, have also been found to enter the body of zooplankton. The zooplankton are known to capture suspended particulate matter. It is, therefore, possible that they also take up particulate hydrocarbons directly from the sea.

What happens to these hydrocarbons in the body of zooplankton? There are evidences that several types of hydrocarbons may be metabolised by certain marine animals including zooplankton, but many animals cannot metabolise hydrocarbons; some of the hydrocarbons may pass out unchanged. Zooplankton, such as copepods, euphausids, amphipods, zoea of crab and jellyfishes, have been found to metabolise hydrocarbons such as napthalene, benzo (a) pyrene, octadecane and 20-methylcholanthrene. The metabolites


Jelly Fish

Copepods

Diatom

Radiolaria

[illegible] fore, these are available for transfer to a higher trophic level. The hydrocarbons are also released by zooplankton in their feces and thus reach bottom-dwelling sedentary animals.

Crude oil in high concentrations is lethal to many zooplanktonic forms like copepods *(Acartia, Centropagus)* and their larvae. It also inhibits their feeding rates. The respiratory rate increases affecting the rate of oxygen consumption and this in turn affects their locomotion. The larvae of the lobster, *Homarus americanus*, when exposed to 1 mg/l of South Louisiana crude oil showed lowered feeding activity and power of locomotion, and a high rate of mortality. The petroleum hydrocarbons are said to influence moulting, sex-ratio and reproduction in zooplankton. Certain hydrocarbons reduce the rate of viability of eggs.

It is interesting to note that at very low concentrations hydrocarbons enhance photosynthesis in phytoplankton. But thick oil slicks may reduce penetration of light through sea water by more than 90 per cent and thus drastically reduce the rate of photosynthesis.

A number of marine animals including fish and mammals contain what is called mixed function oxygenases (MFO) which help in the metabolism of petroleum hydrocarbons While some hydrocarbons may be removed from the animals by metabolic changes, others are likely to increase the carcinogenic potential of these compounds. It has also been seen that there is a greater incidence of neoplasia (growth of tumour) in fish from contaminated localities

Heavy metals are the other pollutants to be monitored. It is difficult to define heavy metals. The metals of atomic numbers 22 [illegible] periodic table are usually included in heavy metals. According to another definition, metals having specific gravity greater than four are known as heavy metals.

All heavy metals are relatively poisonous to animals, both microscopic as well as macroscopic. The metal concentration in the sea is gradually increasing due to industrial effluents, mining operations, burning of fossil fuels and other factors. Heavy metals also move up to the higher trophic levels through marine food chains and ultimately reach human beings.

A metal in the sea water may be present in the particulate form and/or in solution. The particulate forms result from either the precipitation of an insoluble compound of the element such as chromium hydroxide or lead carbonate or absorption of the metal ions on to other particulate materials such as clay, minerals and organic detritus in the water. It is difficult to know the chemical nature of the dissolved forms and many of these compounds may become more complex by combing with the organic matter dissolved in sea water.

Phytoplankton provide a very large surface of adsorption and consequently play a very important role in metal uptake. However, exactly which chemical compounds enter the phytoplankton is not known but it has been suggested that the organically bound metals are not taken up by the phytoplankton.

Experimentally it has been shown that the toxic effect of heavy metals on phytoplankton depends on various factors such as: (1) the species of phytoplankton, (2) cell population, (3) composition of sea water, and (4) concentration of the heavy metal. The metals probably increase the permeability of the [illegible] of cell contents. They may also reduce the rate of cell division and thus affect the growth rate of phytoplankton.

Heavy metals may be either (1) adsorbed on to their body surface and gills from water passing through these parts, or (2) ingested as detrital particles and contaminated food. The metals from any part of the body ultimately enter the tissues and from there they are eliminated in four ways: (1) by moulting (casting off the outer skeleton), (2) fecal pellet formation, (3) soluble excretion, and (4) egg production.

Heavy metals reduce the metabolic activities of zooplankton; the rate of oxygen consumption is also reduced. However, this will again vary with salinity and temperature conditions. The metals also reduce the rate of feeding, growth and development. The hatching of eggs and subsequent planktonic stages are also affected. The egg-production itself may be reduced and practically stop at high concentration of metals. The metals also affect the phototactic responses and consequently the vertical migration. This phenomenon is very important since it enables the zooplankton to find out suitable habitats, avoid predators and capture food.

Almost every major group of zooplankton journeys daily from deeper waters to the surface at the approach of dusk and returns to deeper waters at dawn. This is known as vertical migration or diurnal migration.

The swimming rates too drop due to metals toxicity. The number of individuals, species and groups of zooplankton ultimately decreases.

Insecticides, herbicides, fungicides, algicides, helminthicides, rodenticides, fumi-

Zoea of crab

Box-jelly

Zoea of crab

Portuguese-man-of-war

krill *(Euphausia superta)*. According to one estimate the standing stock of Antarctic krill is from 800 to 5,000 million tonnes. And, predictions of annual yield vary from about 100 million tonnes to 200 million tonnes.

The marine scientists place the zooplankton under three main heads: (1) fish-related, (2) fishing-related, and (3) exploitable plankton, on the basis of their relationship with different fishes and fisheries. The fish-related plankton may be beneficial or injurious to fish. These may form direct food for the fish, or an indirect food in the sense that some other animals may feed on the zooplankton which in turn are eaten by the fish. The relationship between the number of krills in an area and the whale catch and that between the calanoid copepods and herring catch are examples of direct food plankton. Thus an analysis of the plankton sample can provide a clear indication of the prospective total fish catch.

gants. etc are carried to the sea through sewage. industrial effluent. water runoff from agricultural land and as dust from the atmosphere. The main hazardous effect of pesticides. especially of chlorinated hydrocarbons, is the ability of their residues to get concentrated in marine organisms; the increase in the concentration of residues is higher at higher trophic levels. Therefore. even if the pesticides are released into the sea in very low concentrations they build up and are likely to be found in large quantities in tertiary consumers such as fish and eventually reach man.

Chlorinated hydrocarbon pesticides disturb the metabolism of the organisms in various ways. DDT in very low concentration (a few parts per billion) reduces the rate of photosynthesis in phytoplankton. DDT has also been found to prevent metamorphosis of the larvae of marine organisms.

The pollution due to discharge of heated effluents in the coastal waters and estuaries is very significant, since almost all the marine zooplankton live near their upper limits of temperature tolerance. Thus even a slight rise in the temperature of sea water will affect them in different ways; thermal shock may even kill them. In tropical waters, the effect is more prominent. Experiments carried out by the author on different zooplankton off our coastal waters have shown that these animals cannot survive at temperatures higher than 35° or 36° C. Therefore, in summer any increase in temperature of 3° to 4° C above the normal is lethal to these animals.

It is also known that increase in the temperature of sea water affects respiration, heart beat, reproduction, development and other physiological processes of marine zooplankton. Oxygen solubility falls with the increase in temperature.

Thermal pollution generally occurs due to discharge of warm cooling water from thermal and nuclear power plants. This is because even in most efficient nuclear power plants only about 40 per cent of the heat produced by the reactor is actually used for generating current. The remaining heat mostly ends up in the cooling water. Sometimes, the temperature may rise by 14° C or more.

The radioactive pollutants affect the organisms chiefly by ionisation from radiations emitted by radioactive materials on Earth. (The Earth also receives radiations from space.) The amounts of radioactive waters discharged into the sea are likely to increase with more atomic power stations, nuclear reactors, nuclear explosions and medical and other uses of nuclear energy.

Radionuclides (isotopes of elements that emit ionising radiations) reaching the sea may remain in solution or in suspension, or precipitate at the bottom. The radionuclides quite often disperse and get diluted due to currents and water turbulence, or may get accumulated. If the input exceeds the rate of natural radioactive decay, they may also be taken up by marine plants and animals, and get concentrated in living organisms. This is known as bioaccumulation.

The phytoplankton concentrate radionuclides by absorption and surface adsorption. Millions of rapidly dividing phytoplankton cells can accumulate a large quantity of radionuclides from sea water in a very short time.

So far more than 60 radionuclides have been identified within the marine system. It has been observed that different dose rates affect the phytoplankton, zooplankton and other organisms in the food chain differently due to various factors such as body size, physiological state and age. In the sea, the interaction of environmental factors such as temperature, salinity, dissolved oxygen, chemical composition, and geochemical cycles, are also responsible for further complication of the effect of different doses on the organisms. The amount of radionuclides that enter food chains and ultimately reaches man, therefore, does not depend entirely on the amount of radionuclides discharged.

Experiments show that very low levels of chronic radiation do not affect the growth of phytoplankton. But, large doses of it are lethal to both phytoplankton and zooplankton. Experiments on the lethal values of different radionuclides on marine organisms have been few, but the level of radiation required to kill marine organisms is very high. In fact, experimental data indicate that LD 50/30, the lethal does in which 50 per cent of the animals die in 30 days, ranges from 2,000R to 11,000 R for invertebrates and 1,050 R to 5,550 R for marine fishes. Since most of the marine zooplankton, like all the primitive life forms, are more resistant to radiation than the higher forms in the food chain in the sea (the eggs and larvae are also equally resistant to radiation), radioactive pollution may not kill but produce various abnormalities in the young and adult stages of the higher forms. It is difficult to accurately predict the effects of radioactive pollution on phytoplankton, zooplankton and animals of higher trophic level.

S. S. B.

The injurious plankton may be spawn predatory, that is, feeding on the eggs or larvae of fishes. They may also feed on the other smaller varieties of zooplankton, and thus consume large amounts of food which could otherwise be the food for fish larvae. The presence of injurious plankton such as comb-jellies, jellyfishes or even small protozoa like *Noctiluca*, indicates a decrease in fish catch.

The fishing-related plankton are those which either help or obstruct fish catching—they are either the fish-indicator-plankton or the fisherman-disabling-plankton. The fish-indicator-plankton, as the name suggests, indicate the presence of a fish in an area, although they may not have any food relationship with the fish. Then there are the adverse-indicator-plankton whose presence could indicate absence of the fish. The presence of *Noctiluca* always coincides with a poor catch of mackeral.

The fisherman-disabling-plankton obstruct fishing in different ways. The presence of certain zooplankton in large numbers makes it difficult to operate the nets. The swarms of jelly fishes or salps may damage the net due to their enormous weight. Certain zooplankton like jellyfish, when they are near the bottom or in deep waters in large numbers, may deceive the echo-sounder of the fishing craft and result in hauling up the useless plankton instead of the fish. There are certain other zooplankton such as *Physalia* (Portuguese-man-of-war) and the jellyfish which are injurious to man; some of the jellyfishes like the box-jelly (*Chironex*) can kill a man in less than a minute (SCIENCE TODAY, June 1977). The catch-plundering-plankton are those which eat up or damage the fish before the catch is hauled up. Some of these zooplankton even eat up the baits.

Exploitable plankton are those which may be used in different ways. These can be divided into immediately-exploitable-plankton or exploitable-in-future-plankton. The immediately-exploitable-plankton again may be of different types. The small planktonic fish like Pomacentrids (*Daya jerdoni*) is used as bait for the tuna fish. The other type is the farm-use-plankton which may be cultured in inshore waters as food for fish, as organic manure for farm lands, or in animal husbandry. Another important group under this category is the human-consumption-plankton.

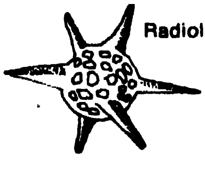
Marine biologists are now trying to find out whether harvesting the zooplankton from the sea and using them directly as human food is more

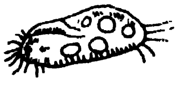
Pontosphaera

Gymnodinium

Tetraselnus

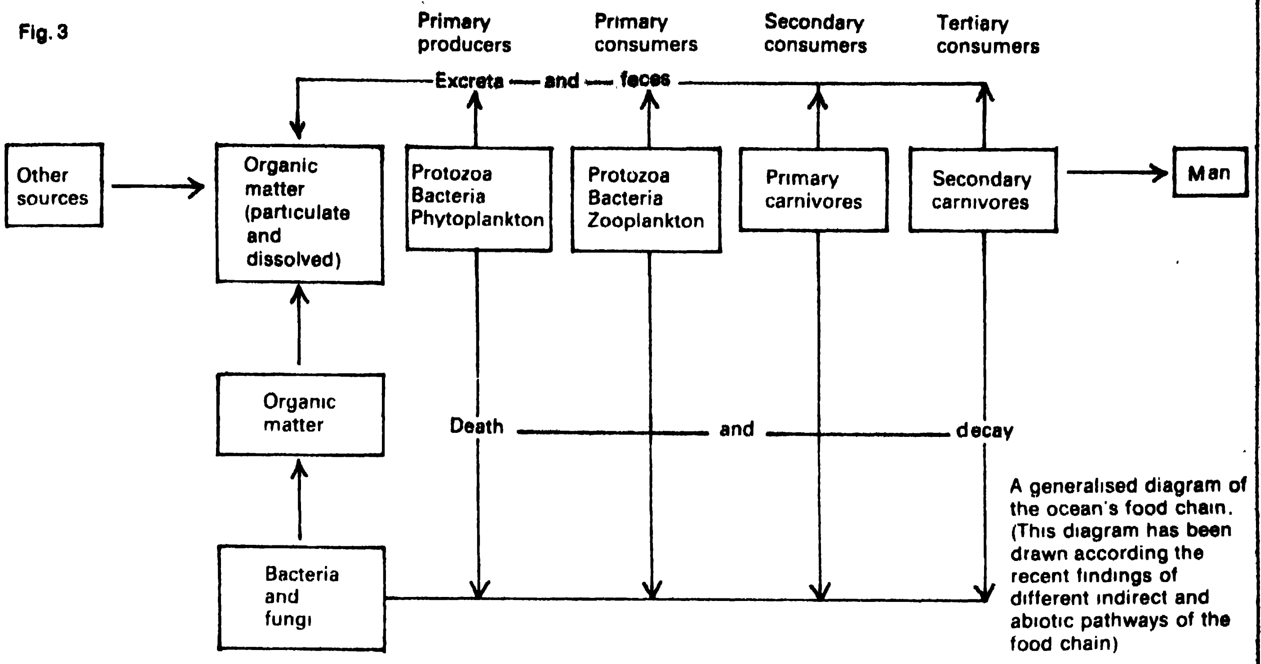
Cryptochrysis


Radiolarian


Foraminifera

Pulvinulina

Fig. 3



A generalised diagram of the ocean's food chain. (This diagram has been drawn according the recent findings of different indirect and abiotic pathways of the food chain)

economical than allowing them to be eaten by fish or other animals and catching those larger organisms. A good example of direct food plankton is euphausides, commonly known as the krill (p 30). The Antarctic krill (*Euphausia superta*) is found in the upper layers of the oceans between the latitudes 50° and 60° S. and the Antarctica. The animals grow to a maximum size of about 70 mm and the swarms may attain a density of 10 to 16 kg per cubic metre. About 100 million tonne of Antarctic krill can be caught each year. The annual production has reached up to 10,000 tonne per year in Japan. Krill fishery is also popular in the USSR, Norway and the UK.

Krill is processed in various ways for direct human consumption or put to other uses. In Japan, they are either frozen in the raw state, or dried after boiling. In Russia, a shrimp paste known as ocean paste is produced by squeezing shrimp under pressure and coagulating the protein present in the filtrate by heat. The paste is mixed with butter, cheese and other products. It contains about 13 to 20 per cent protein and is rich in essential amino acids. In Maharashtra, the mysids, commonly known as *Jawla*, are used as food.

The zooplankton consisting of fish eggs and larvae are the exploitable-in-future plankton. The eggs and larvae are ultimately transformed into pelagic or demersal fishes. Some of them may migrate away to different localities. In the early stages, fishes are susceptible to large-scale mortality due to the presence of certain zooplankton and physical and chemical factors of the environment.

In the early years of planktology, the limited knowledge permitted only qualitative and quantitative studies of the organisms. The plankton were collected for mere indentification and classification. Soon it was realised that zooplankton form very important links in the food chains in the sea or any aquatic medium and that their number and species composition vary with the seasons and to changes in the physical, chemical and other environmental factors. It is not always possible to study these organisms in the field. The present trend of research is, therefore, to keep them alive in the laboratory and culture them in order to study their behaviour under controlled conditions and then correlate the results with the observations.

Can we raise the fish yields? With the advancement of fishing technology, the annual production of marine animals may increase to some extent, but there is always an upper limit. Hunting and catching methods for harvesting marine animals might be prefected to a point (according to some the point has already been reached) beyond which overfishing will result. And it is already known that overfishing results in decline in fish catch in the future. Is it possible to develop some methods in the sea comparable to the terrestrial agriculture? In fact, marine biologists are trying to develop coastal aquaculture by which either any one species of animals or several species of animals such as prawns, oysters, mussels and fishes may be grown; they have indeed been partly successful. But to introduce aquaculture, a detailed knowledge of zooplankton is essential since almost all commercial fish eggs and larvae are planktonic and moreover the fish also feed on zooplankton. Therefore, the behaviour of these larvae and eggs during their planktonic stages and also the life-cycle and behavioural pattern of other marine zooplankton must be understood for a successful method of culture.

Since marine zooplankton are an important item in the food chain they are responsible to a great extent for the transfer of several pollutants to man via fish and other marine animals. The pollutants like heavy metals, hydrocarbons, pesticides, etc affect the brain, muscles, bones and several other organs in the human body so as to cause various diseases and disorders and even death. Another aspect of pollution studies is, therefore, to find out how these organisms gather the pollutants, what happens to these organisms in different concentrations of the pollutants and consequently to the fisheries, and how do they transfer these pollutants to other animals in higher trophic levels of the food chain and ultimately to man

Dr. Bhattacharya who is with the Department of Zoology, Siddharth College of Arts and Science, obtained his Ph D in Marine Zoology His research work includes experiments on various live marine zooplankton like copepods, post-larvae of prawn, *Acetes*, mysids, *Lucife* medusae, ctenophores and others in th laboratory with reference to their salinit and temperature tolerance

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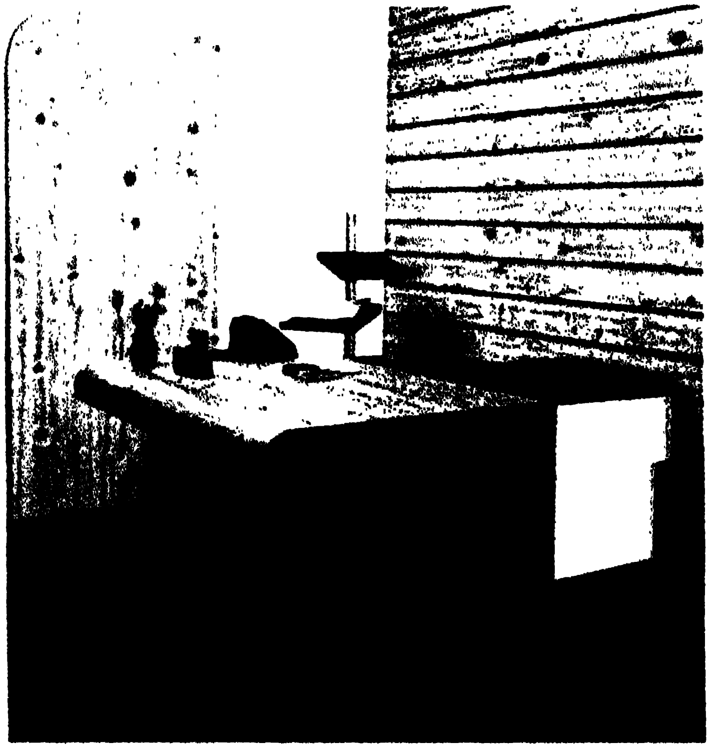

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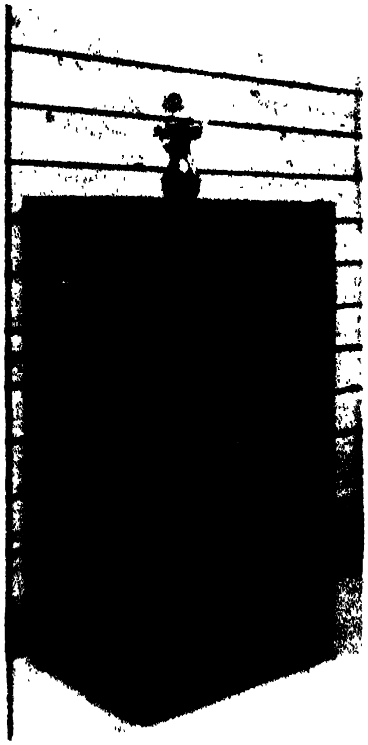

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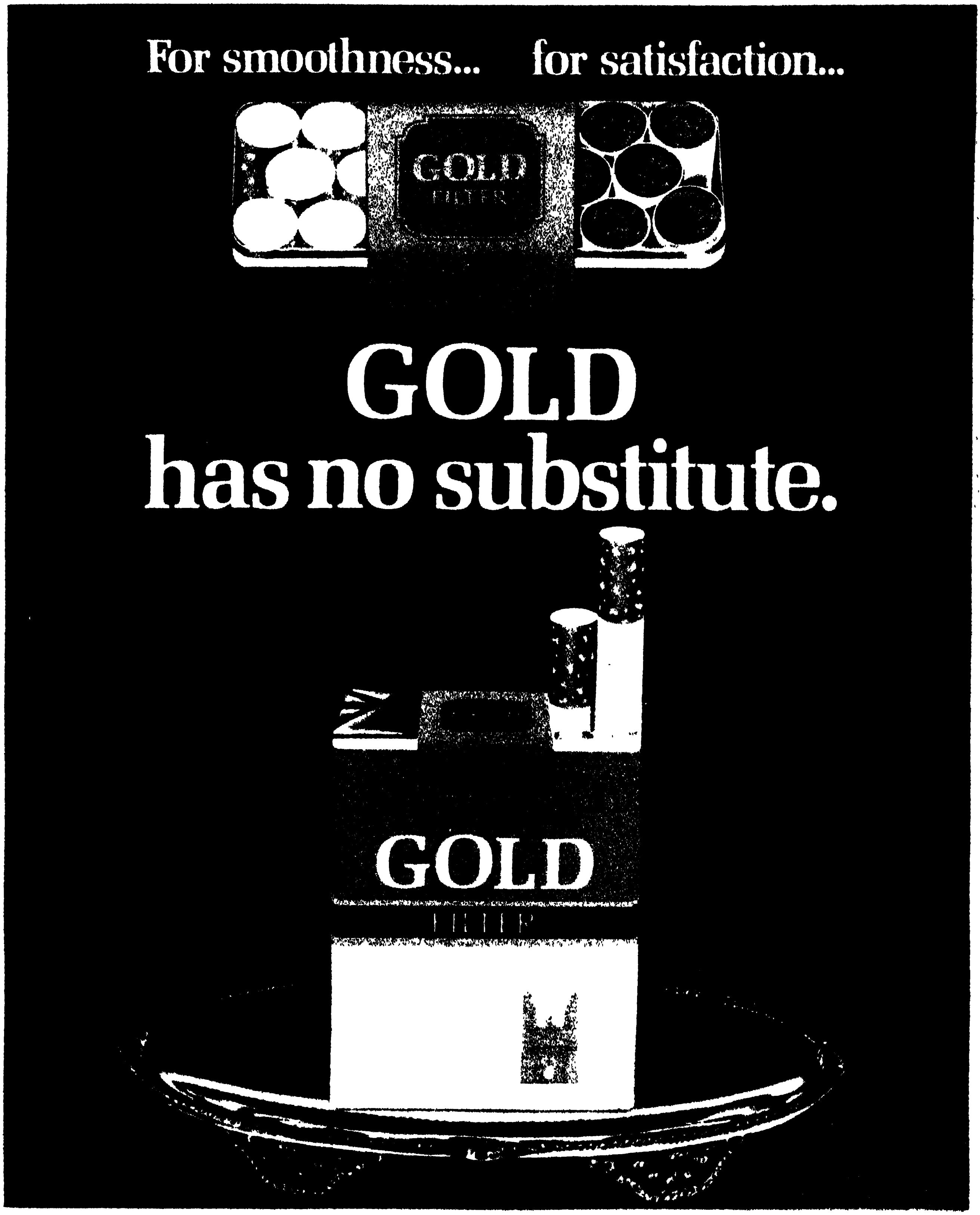

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The fascinating Fibonacci numbers

Basil Davis

Fibonacci numbers turn up everywhere around us in stable atomic nuclei, in composite flowers, in beautiful paintings and even poems

THE Fibonacci numbers form an intriguing sequence first described in the 13th century by the Italian mathematician, Leonardo Fibonacci, after whom they are named. They turn up in the most unexpected areas: to name a few—in chemistry, botany, architecture and even in celebrated paintings. Why they do so is controversial. Some ascribe it to divinity, some to natural law but all agree about their fascination. There is now a Fibonacci Association based in California, USA. Adherents of the Fibonacci cult are known somewhat irreverently as 'Fibonacci nuts', but the Association since 1963 regularly publishes *The Fibonacci Quarterly*, a journal devoted to the properties of the Fibonacci sequence and related topics in number theory. One need not, however, be a mathematician to explore the fascinating properties of the Fibonacci numbers. A working knowledge of simple arithmetic is sufficient for anyone to explore their fascinating properties and discover endless theorems and regularities.

Actually, Fibonacci did not study deeply the sequence named after him. The sequence was studied in depth by Edouard Lucas, a 19th century French mathematician who gave it the name. He was studying the behaviour of sequences which start with *any* two numbers, every subsequent number in the sequence then being derived by adding the two preceding numbers. One such sequence is 1, 3, 4, 7, 11; 18, 29 . . . now known as the Lucas series. The Fibonacci sequence—1, 1, 2, 3, 5, 8, . . .— is the simplest of such sequences. The first twelve terms of the Fibonacci sequence are shown in Table 1.

Take a look at the ratio of consecutive Fibonacci numbers. As we go to larger and larger Fibonacci numbers we shall find that the ratio gets closer and closer to $(1+\sqrt{5})/2$. This limiting value, approximately 1.618. . .. is called the golden ratio and is one of the most important features of the Fibonacci sequence.

Fibonacci numbers are important in processes of growth. The now famous problem which Fibonacci described, and which gave the sequence its name, concerns rabbits and their growth. A male-female pair of rabbits is kept in an enclosure. Any new pair does not yield progeny till the end of its first month. Every pair thereafter gives birth to a male-female pair every month.

Assuming that none of the pairs dies and that the original pair bears its first pair in the first month, how many pairs will there be at the end of one year? It turns out that the number of pairs in the enclosure at the end of each month—2, 3, 5, 8, 13, 21, 34, 55, 89, 144, 233, 377 is always a Fibonacci number (the growth of rabbits at the end of each month is shown in Fig. 1 for the first five months).

Fibonacci numbers appear in innumerable instances in plant growth and structure. Take a pineapple. It has a number of "eyes", wart-like thorny projections, on its surface. The eyes are arranged in two sets of spirals, one moving in a clockwise and the other in a counterclockwise direction. The number of spirals measured in one direction and that in the other are invariably consecutive Fibonacci numbers (Fig. 2). A composite flower like the sunflower has disc and ray florets. The disc florets are arranged in spirals running clockwise and counterclockwise. The number of spirals here, too, will be close to consecutive Fibonacci numbers. It could be a profitable hobby to observe growth processes and discover the Fibonacci sequence occurring in different ways in different plants.

Fibonacci numbers also turn up inside atoms. The nucleus of an atom is a tightly packed collection of positively charged protons and the electrically neutral neutrons. The number of protons, which is equal to the number of electrons, is called the atomic number and designated by Z.

Table 1 The Fibonacci sequence

Serial number	Fibonacci number	Ratio of consecutive numbers *
1	1	—
2	1	1.000
3	2	2.000
4	3	1.500
5	5	1.667
6	8	1.600
7	13	1.625
8	21	1.615
9	34	1.619
10	55	1.618
11	89	1.618
12	144	1.618
...	...	...

*Up to three decimal places.

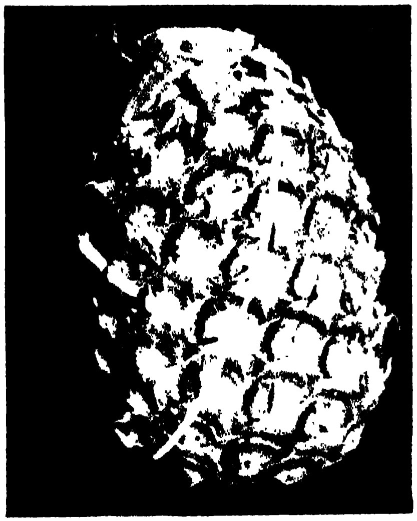

D V Cooney

Fig 2 This pineapple has 8 spirals in the direction parallel to the dotted line and 13 in that parallel to the solid line both Fibonacci numbers

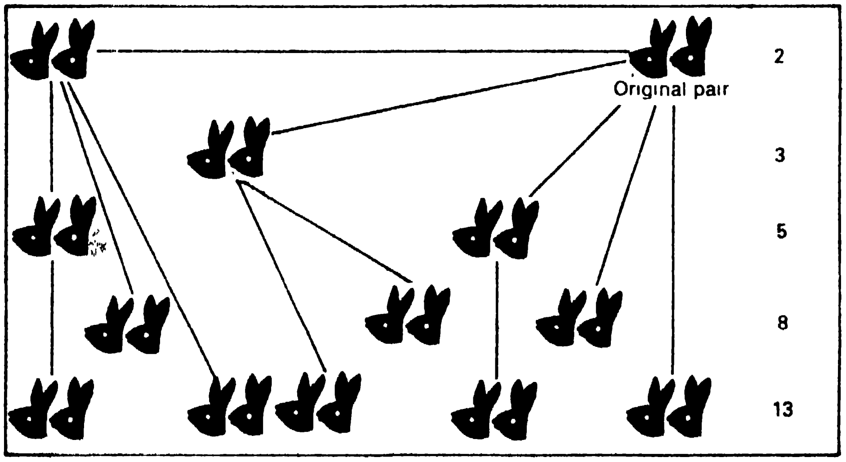


Fig 1. In Fibonacci's rabbit problem the number of rabbits in the enclosure at the end of every month is a Fibonacci number

Table 2 Inert gases follow Fibonacci

Gas	Symbol	Atomic number	Nearest Fibonacci number
Helium	He	22	2
Neon	Ne	10	13
Argon	Ar	18	21
Krypton	Kr	36	34
Xenon	Xe	54	55
Radon	Rn	86	89

Table 3 Fibonacci and nuclear stability

Magic number (x)	$x/10$	Nearest integer
2	0.2	0
8	0.8	1
14	1.4	1
20	2.0	2
28	2.8	3
50	5.0	5
82	8.2	8
126	12.6	13

The chemical properties of an element are determined solely by its atomic number.

Elements combine with others to form chemical compounds. But the inert gases are exceptions; their configurations are very stable and it is only with the greatest difficulty that they take part in chemical reactions. Table 2 gives the atomic numbers of these inert gases; it shows that the atomic numbers of the heavier atoms are strikingly close to the Fibonacci numbers 13, 21, 34, 55 and 89.

Some mathematical properties of Fibonacci numbers

ADD one to the golden ratio associated with Fibonacci numbers and you get its square. Add the ratio itself to the square and you get its cube Add the square to the cube and you get its fourth power You can continue with this as long as you like to get higher and higher powers of the golden ratio.

Alternatively, subtract one from the golden ratio and you get its reciprocal. Subtract the reciprocal from one and you get the square of the reciprocal. Subtract the square of the reciprocal from the reciprocal itself and you get the cube of the reciprocal. You can continue this as long as you like, to get higher and higher powers of the reciprocal of the golden ratio. By simple addition and subtraction you can raise the golden ratio or its reciprocal to as high a power as you like.

This is only one of the many remarkable properties associated with Fibonacci numbers, but before we take a closer look we shall have to get the Fibonacci sequence in order Each of the Fibonacci numbers in the sequence is denoted by F_n where n refers to the place of the number in the sequence. Thus, from Table 1, we can see that $F_1=F_2=1$, $F_3=2$, $F_{12}=144$ and so on Mathematicians add a further term at the beginning of the sequence, $F_0=0$, to round off the sequence The terms of the sequence are related to one another by the condition that each term is the sum of the two preceding terms, that is, $F_{n+2}=F_{n+1}+F_n$ The sequence then appears as follows

F_0	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9
0	1	1	2	3	5	8	13	21	34

We are now all set to look at some mathematical properties of the Fibonacci sequence. The sum of two consecutive Fibonacci numbers is, of course, the next Fibonacci number. But, the sum of the *squares* of two consecutive Fibonacci numbers is also a Fibonacci number. This can be easily verified for a few of the numbers from the table.

$$1^2+1^2 = 2$$
$$1^2+2^2 = 5$$
$$2^2+3^2 = 13$$
$$3^2+5^2 = 34$$

This is actually a special case of a more general property. Take two pairs of consecutive Fibonacci numbers. Multiply together the first from each pair and the other from each pair and add the products. The resultant number will again be a Fibonacci number.

$$1\times3+2\times5 = 3+10 = 13$$
$$3\times13+5\times21 = 39+105 = 144$$
$$2\times8+3\times13 = 16+39 = 55$$

The algebraic formula specifies also *which* Fibonacci number will result. Thus, if the pairs are F_n, F_{n+1} and F_m, F_{m+1}, then the result $(F_nF_m+F_{n+1}F_{m+1})$ will be the Fibonacci number F_{n+m+1} The earlier example of the sum of squares of consecutive numbers is only a special case in which the pairs are identical and n=m so that the result is the Fibonacci number F_{2n+1} The readers can easily verify this from Table 1.

The subscript n denotes the place of the Fibonacci number in the sequence. If turns out that if the subscript of one Fibonacci number is divisible by that of another then the number itself is divisible by the Fibonacci number corresponding to the other subscript. Thus since 12 is divisible by 6, $F_{12} = 144$ is divisible by $F_6 = 8$, or since 14 is divisible by 7, $F_{14} = 377$ is divisible by $F_7 = 13$.

Among all the Fibonacci numbers there is only one square number (we make an exception of the trivial cases of $F_0 = 0$ and $F_1=F_2=1$) and that, incidentally, is also the square of its subscript $F_{12} = 144 = 12^2$!

The ratio of two consecutive numbers of their sequence is one of the most important properties of the Fibonacci numbers. Starting from the definition of the Fibonacci numbers, we can write:

$$F_{n+1} = F_n + F_{n-1}$$

$$F_{n+1}/F_n = 1 + F_{n-1}/F_n$$
$$= 1+\frac{1}{(F_n/F_{n-1})}$$

Now, in the last expression above, F_n/F_{n-1} can obviously be replaced by a similar expression and soon we have a long continuing fraction.

$$F_{n+1}/F_n = 1+\cfrac{1}{1+\cfrac{1}{1+\cfrac{1}{1+\cfrac{1}{1+\ldots}}}}$$

As n tends to infinity the continuing fraction also becomes infinite and the formidable looking expression can be evaluated quite simply. Let the expression be x, then obviously the shaded portion is also x. So,

$$x = 1 + 1/x$$

$$x^2 = x+1$$

$$\text{or } x^2-x-1=0$$

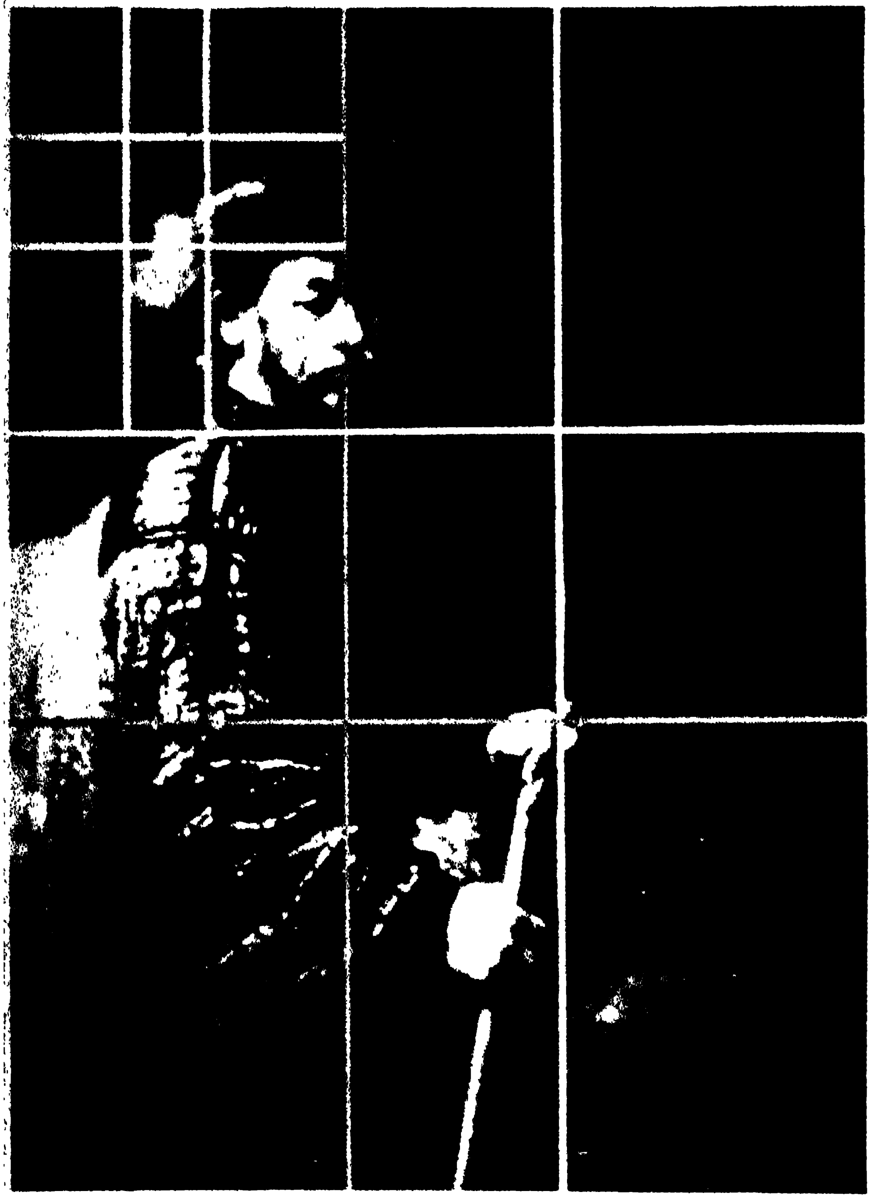
This equation has two roots, of which the positive one,

$$\alpha = \frac{1+\sqrt{5}}{2},$$

is the golden ratio. The magic value of 1.618... is nothing but $(1+\sqrt{5})/2$ expressed up to three decimal places.

The properties of the golden ratio we mentioned in the beginning are simply the result of the equation $x^2 = x + 1$ that α satisfies. So, $\alpha+\alpha^2=\alpha(1+\alpha) = \alpha\times\alpha^2=\alpha^3$ and so on. Similarly arranging our equation we get $\alpha^2-\alpha=1$, or dividing throughout by α, $\alpha-1=1/\alpha$ Then, $1-1/\alpha = 1/\alpha(\alpha-1) = 1/\alpha \cdot 1/\alpha = 1/\alpha^2$ and so on. Any power, therefore, of the golden ratio can be derived from α simply by addition and subtraction.

B. D.



J.J. School of Art, Bombay

Rembrandt and the golden ratio

ART cannot be encapsulated into a rigid formula and the Fibonacci sequence and its golden ratio are no exception. The golden proportion is only one among many aesthetic values which will be crucially dependent on the artist, the aesthetic assumptions of his age and its socio-economic milieu. One must also distinguish between regularities which train and sharpen one's sensibilities without confining them and those which serve rather to constrain them.

If we keep this firmly in mind, we will be able to enjoy the near-ubiquitous appearance of Fibonacci numbers in the patterns around us without their encroaching upon reason and creativity. Here is a portrait by Rembrandt which turns around the golden ratio. The picture frame has been divided into rectangles formed by the points which divide the sides of the frame in the golden ratio. The smaller rectangles in the upper left corner are similarly obtained by dividing the sides of the small rectangle, again in golden ratio. The main elements of the picture can then be seen to turn around these divisions, of which we describe a few below. Readers can discover many more on their own

The head, the important element of the picture, has a rectangle, formed by the blue dividing lines, all to itself. The hand, another important part of the picture, also has a similar rectangle all to itself. The further smaller divisions show that the highest lights on the face all fall into one rectangle in these subdivisions Within their respective rectangles, the head lies on a line of the golden section as does the upper hand, the other highlight of the portrait.

D. T. PADEKAR

Mr. Padekar was a lecturer at the J.J Institute of Applied Art and is presently with the Art Department, Times of India

Just as atoms participate in chemical reactions, the nucleus takes part in nuclear reactions, which are the source of nuclear energy. Here, too, there are stable and unstable nuclei. Experiments show that nuclei having either their number of protons or neutrons equal to 2, 8, 14, 20, 28, 50, 82 and 126 are exceptionally stable. The significance of these "magic numbers" remained a mystery till it was finally explained by the shell model of the nucleus.

At first sight these magic numbers do not seem to have anything to do with Fibonacci numbers. But divide them by 10 and round them off to the nearest integer and we have the terms of the Fibonacci sequence (Table 3)! Whether in the atom or in the nucleus, Fibonacci spells stability.

In the late nineteenth century, Adolf Zeising, a German, wrote a book about the golden ratio, the limit to which the ratio of consecutive Fibonacci numbers approaches. This classic treatise puts forward the view that the golden ratio is the artistically most pleasing of all proportions. Zeising further argues that the golden ratio also plays a fundamental role in the structure of living things including the human body. He asserts that the average ratio between the height of a man and the height of his navel is the golden ratio.

This assertion is in the process of being tested by biologists T. A. Davis and R. Alterogt. Their measurements of subjects from India and West Germany show an average close to 1.618. Proportionate lengths of legs to body heights, however, varies for different countries and more experiments from more countries are needed in order to generalise.

The aesthetic appeal of proportions in the golden ratio can be very easily seen. If we draw a number of rectangles, then it is most likely that the rectangle we pick out as the most pleasing will be a golden rectangle, a rectangle whose sides are in the proportion of the golden ratio. The ancient Greeks incorporated the golden ratio in their architecture; a golden rectangle fits exactly over the facade of the famous Parthenon. The golden ratio can be found in many paintings. G. E. Duckworth has even produced evidence that it can be found in the constructions of famous Latin poets like Virgil, Lucretius and Horace.

Fig 3. Pine cones contain spirals close to Fibonacci numbers, in this case 5 and 8

The golden ratio of the Fibonacci sequence is also important in music. H. E. Huntley says, "There are three emotionally potent musical intervals which stand out from all others by virtue of their consonance: they are the unison, the octave and the major sixth. These are aesthetically pleasing because . . . these pairs of tones produce no beats between their harmonics." It turns out that the intervals of the unison (the notes C' and C'), the octave (the notes C'' and C') and the major sixth (the notes C'' and E) are characterised by the ratio of frequencies of 1:1, 2:1 and 8:5, respectively, all of them Fibonacci numbers. Even in a piano keyboard the Fibonacci numbers are apparent. An octave of the piano keyboard consists of a group of 2 black keys and another of 3 black keys, making a total of 5 black keys for the octave along with a total of 8 white keys, making a grand total of 13 keys for the octave.

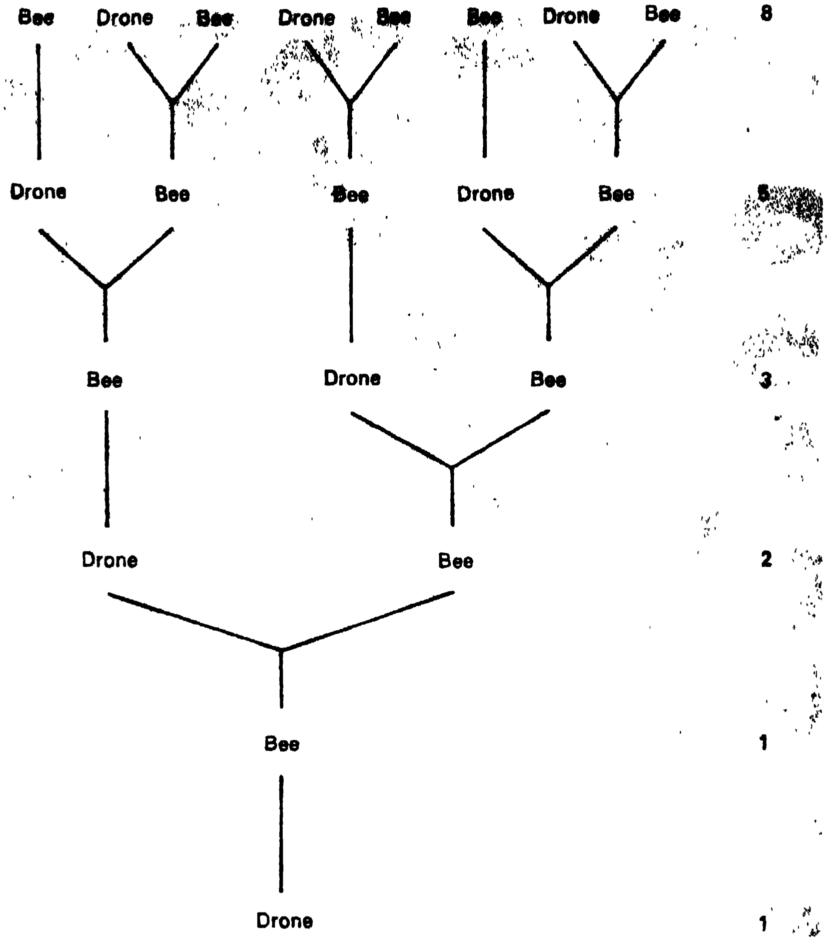


Fig 4 The drone's ancestral tree. The number of ancestors in a generation duplicate the Fibonacci sequence

The Fibonacci kingdom has many more areas and a number of books have already been written about it. The three references below will help the more interested reader to get acquainted with some of its pathways. We shall close the article by describing Fibonacci numbers in the ancestors of male-bees or drones.

The male bee, or the drone, hatches from an unfertilised egg. Thus he has a mother but no father. His mother, however, being female, hatched from a fertilised egg. Thus he has two grandparents. Of these, the grandfather had one parent and the grandmother two and so on. If we now climb up the ancestral tree of a drone, the numbers of ancestors in any one generation form an exact replica of the Fibonacci sequence (Fig. 4)!

A gleam of light

THE Middle Ages (from about 800 AD to 1450 AD) were a period of stagnation and gloom for European mathematics. In this darkness, a gleam of light showed up briefly with Leonardo of Pisa. Now more famous by his patronym Fibonacci (the son of Bonacci), he was the only outstanding European mathematician of this period.

The famous sequence named after Fibonacci occurs in a problem he handles in passing in his magnum opus, *Liber Abaci* (the Book of the Abacus), published in 1202. In it he demonstrated the efficacy of the Indian-Arabic numeral system, which is now in general use, and advocated its use for calculations. He was perhaps very well-suited to do this. Though born at Pisa, the city famous for its leaning tower, in North Italy, he spent his childhood in North Africa where his father was in charge of a custom house. Thus, he was practically brought up on this numeral system.

Through *Liber Abaci*, Fibonacci also transmitted to Europe the major achievements of West and South Asia in trigonometry. This itself should have won him a place in the history of European mathematics, though a later work, *Algorismus* by John Holywood, published in 1240 became more popular and was still being reprinted in the seventeenth century.

Fibonacci was also a mathematician in his own right. It may look deceptively easy but it took a genius to sift and select from the Arabs their major achievements. He also discussed the rudiments of an 'algebra', and calculated π to be between 3.1410 and 3.1427, a closer approximation than that of Archimedes. He attempted to make meaning out of expressions like "5 diminished by eight" which he put as "a debt of 3" prefiguring the concept of negative numbers. But he was far too much ahead of his times for any of his results to be built upon and developed by his contemporaries.

P. V. P.

Br Davis is lecturer in physics at St. Edmund's College, Shillong, and is currently engaged in research in theoretical nuclear physics.

Recommends reading. **1.** *The Fibonacci Quarterly*, University of Santa Clara California 95053,USA; **2.** *The Divine Proportion: A Study in Mathematical Beauty*, H E. Huntley, Dover, New York, 1970, **3.** *Structural Patterns and Proportions in Virgil's Aeneid*, G. E. Duckworth, University of Michigan Press, 1962.

ROUND-UP OF RESEARCH

Designing non-virulent bacteria for live vaccines

DRUG resistant plasmids (R-factors) were first identified in Japan around 1960. These autonomously replicating genetic elements which make their bacterial hosts resistant to one or several anti-bacterial drugs are widely transmissible among bacteria. Detailed investigation of the transfer of the drug resistance between bacteria revealed that the genes determining resistance to specific drugs formed parts of discrete DNA segments which could hop (translocate, transpose) from the plasmids to bacteria or bacteriophage chromosomes and vice versa. Several independent reports describing these translocatable drug resistance elements (transposons) appeared between 1974 and 1976. These elements were found to share several properties with lysogenic bacteriophages and the so-called insertion sequences. For instance, they could occupy a large number of sites, albeit with variable frequency, on a given chromosome and could produce mutations by inserting themselves in the middle of functional genes. They could also cause chromosomal alterations near the sites of these insertions. In addition, they could serve as clean and convenient genetic markers. Due to these and other useful properties, they were soon recognised as powerful tools for genetic manipulations of bacteria. A host of new methods for in vivo genetic rearrangements in bacteria using these drug resistance transposons were soon developed. These methods have found enormous number of applications in bacterial genetics.

S. K. Hoiseth and B. A. D. Stocker (*Nature* **291** 238) of Stanford University, USA, have used transposon-mediated manipulations to develop live and effective vaccines against infections of *Salmonella typhimurium*. For this, they inserted a transposon called Tn*10* in the middle of a gene termed *aroA*, in a virulent strain of *S. typhimurium*. Tn*10* codes for resistance for the antibiotic tetracycline and the gene *aroA* belongs to the aromatic biosynthetic pathway. A mutation in any step of this pathway stops the synthesis of all the aromatic metabolites of the cell including para-aminobenzoic acid (*p*AB) and 2,3-dihydroxybenzoate (DHB) The latter two compounds are not available in the vertebrate tissues and therefore, a mutational block in *aroA* makes the *S. typhimurium* non-virulent in vertebrate tissue.

The block in *aroA* gene caused by the insertion of Tn*10* can be removed by a clean excision of the transposon, which makes the cells tetracycline-sensitive and restores its virulence. This is a rare event occurring with a frequency of approximately 10^{-8}. This reversion frequency, though low, is not acceptable in a vaccine since the virulent revertants are usually highly lethal. (In toxicity tests, less than 20 virulent bacteria injected intraperitoneally killed 50 per cent of experimental mice.) Therefore, the authors made the block in *aroA* essentially non-reversible. For this they made use of another property of Tn*10*, namely, the tendency to cause DNA alterations, within the transposon itself, sometimes extending into adjacent chromosomal genes. They were able to obtain tetracycline-sensitive derivatives of Tn*10* induced mutations in which the block in *aroA* gene was not lifted at a detectable frequency (less than 10^{-11} per bacterium per generation).

Two stable mutants of *aroA* were thus obtained and tested for ability to act as live vaccines to protect against a later challenge with a virulent *S. typhimurium* strain. Both the strains were very effective as vaccines. These results were in striking contrast to the earlier findings by H. G. Robson and S. I. Vas that vaccination by injection of killed *Salmonella* confers only poor protection against a challenge by virulent strain.

Recently, a vaccine against foot and mouth disease (FMD) has been developed using techniques of in vitro genetic engineering. The present paper indicates that the techniques of in vivo genetic engineering using transposons may provide simpler routes to the development of vaccines, at least for bacterial diseases. Though more extensive animal tests as well as human tests will be required before the final decision about the usefulness of such vaccines can be made, the technique is simple and elegant and is likely to find wide-ranging applications.

S. K. MAHAJAN

Dr. Mahajan is with Biology and Agriculture Division, Bhabha Atomic Research Centre, Bombay.

Natural martian laser

PHYSICISTS from NASA have recently observed the first naturally occurring laser. This infrared laser is at work in the upper atmosphere of Mars. Lasers have been produced for the last two decades under highly controlled conditions using sophisticated technology.

Laser is the acronym for "Light Amplification by Stimulated Emission of Radiation" It is produced because of the way radiation interacts with atoms or molecules. In a gas at thermodynamic equilibrium, the lower energy levels are more populated. But by exciting molecules suitably, the situation can be reversed and higher energy levels can be made more populated. This situation is known as population inversion. Now, if a photon having energy equal to the energy difference between the two levels hits an excited molecule, the molecule is *stimulated* to jump to the lower energy level, emitting a photon identical to the incident one. These photons interact with other excited molecules, producing more identical photons. Thus, an avalanche of photons is generated. The light emitted thus is highly coherent and intense.

Depending on the energy difference between the higher and lower energy levels, the emitted radiation may be of long wavelength, such as microwave (Maser), or of short wavelength, such as infrared or visible light (Laser). Hundreds of natural masers have been observed since 1963, in interstellar space, in variable red giant stars, etc. Astronomers were speculating that in the universe, regions could exist where population inversion of molecules, atoms or even nuclei is being induced by high-energy radiation to produce lasers And now they have been rewarded with the first glimpse of a natural laser.

The NASA group led by Michael J. Mumma claims to have observed population inversion in the 10.4 micrometre (μm) transition of carbon dioxide in the upper atmosphere of Mars (*Science* **212** p. 45). They measured the intensity profiles of various lines at 10 4 μm from the radiation coming from Mars with the help of an infrared heterodyne spectrometer during January-April 1980, when the planet was near opposition. Analysis of the intensity profile of R(8) rotational line, one of the many lines of 10.4 μm band, showed that the upper laser level (00^01) for this transition was not in local thermodynamical equilibrium (LTE). They estimated the kinetic temperature of the emission region from the emission line width. From the intensity measurement, it was found that the energy radiated in R(8) line was about a billion times more than it would be if this region of the atmosphere were in LTE.

At pressures typical of the emission region, the upper atmosphere of Mars, the dominant relaxation process for the upper laser level is radiative energy exchange, while that for lower laser level (10^00) is the collisional relaxation. Left to themselves, these levels can come to LTE through their respective relaxation processes. The NASA group attributes the failure of LTE for upper laser level to screening of radiative exchange in the 4.3 µm band by airborne dust. However, at the lower atmosphere where pressure is higher 00°1 level can come to LTE through collisional relaxation. From the integrated line brightness the column density in 00°1 level was estimated to be not less than $2 \times 10^{[illegible]} \pm 2 \times 10^{[illegible]}$/cm^2. The population of 10°0 level, which is at LTE, was found to be about $3 \times 10^{[illegible]}$/cm^2. Thus the 00°1 level is populated more than fifty times as compared to the 10°0 level and, therefore, 'natural lasing' becomes possible on the transition of CO_2 molecules in the mesosphere of Mars.

It is interesting to note that the highest average power laser operated to date — the 'gas dynamic CO_2 laser' — uses a similar mechanism for creating population inversion. However, in the observed natural laser the suggested mechanism for the failure of LTE in 00°1 level seems to be speculative. This can be verified in the laboratory by simulating the conditions existing in the mesosphere of Mars.

ASHISH KUMAR NATH
DHRUBA JYOTI BISWAS

Mosiac views of the south polar regions of Mars taken two years apart. Mariner 9 shapped the photo at the top during a dust storm, and so, much of the surface details are obscured. The photo below, taken in less turbulent weather by Mariner 7 in 1969 shows greater surface details. The airbone dust is responsible for the natural laser

Mr Nath and Mr Biswas are with the Laser Section, Bhabha Atomic Research Centre, Bombay

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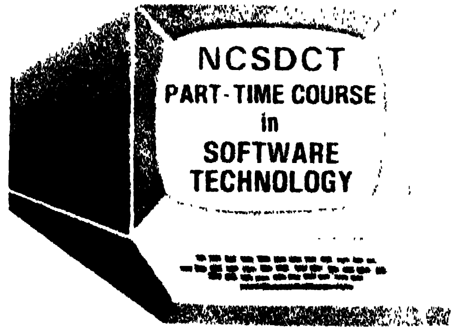

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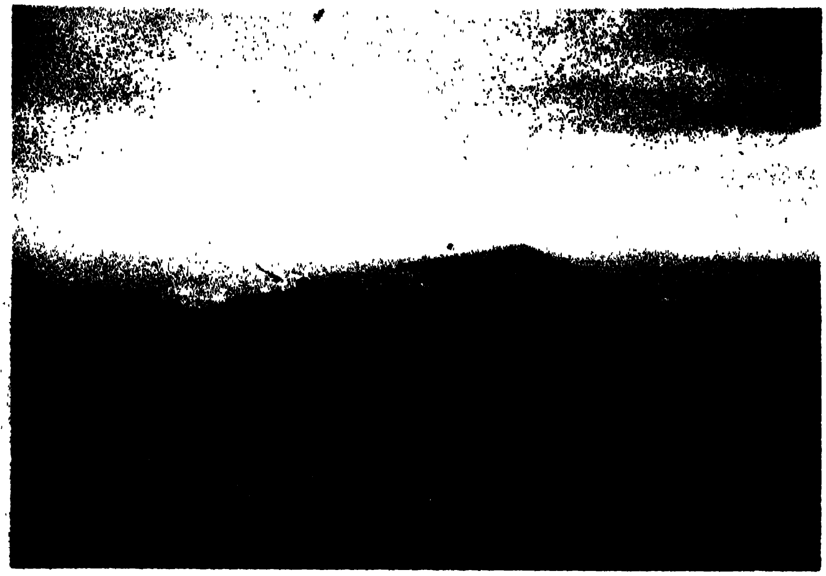
Why do all mountains cast triangular shadows?



The shadow of the Kitt Peak at sunset. Note that the summit is not exactly triangular

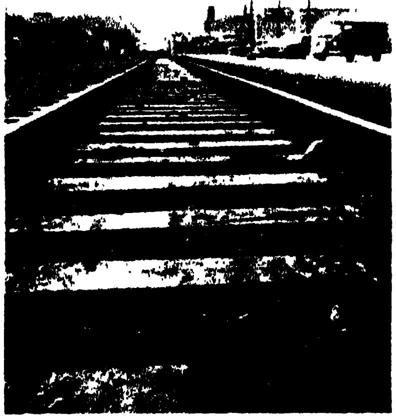
The Spectre of the Brocken as seen from the Cervin, a Swiss alp

A decade or so ago, I saw a particularly memorable sunset in which not only were the colours grand, but in the eastward direction, there was the magnificent shadow of the mountain on which I stood. And what a shadow! It was projected with unbelievable clarity onto the haze of the plains below. A stranger could easily have mistaken this shadow for a real nearby summit. Fortunately my camera was at hand and so the scene was recorded.

For some years thereafter a print of this, Kitt Peak's shadow, hung in my office serving as a conversation piece for countless visiting scientists. Almost everyone remarked on the sharpness of the shadow, with a perceptive few commenting on the presence in the sky of faint twilight rays. But no one, myself included, recognised that this mountain shadow violated the expectation that a shadow should mimic its owner.

Until one day, a young student, Kathy DeGioia, asked: "Sir, how come, though the Kitt Peak is flat, its shadow is pointed?" I mumbled something about the laws of geometrical optics. But in fact I was stumped.

Kathy's question evoked two responses: the first was to work out the answer using the laws of physics (which was done) and, second, to search the literature for previous reports (since "there is nothing new under the Sun", at least in everyday experience).



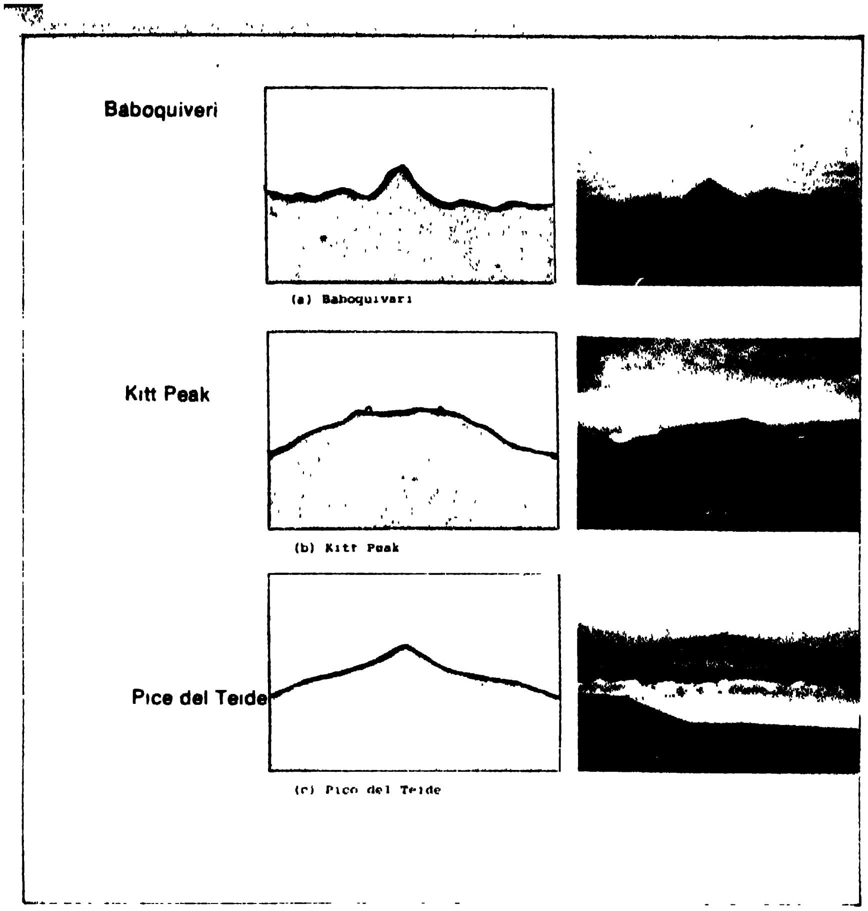
The role of perspective is similar to the apparent convergence of railway tracks. We know that the tracks are horizontal yet they appear to meet at a distance

The "Spectre of the Brocken" from *L'Atmosphere* by C. Flammerion is a case of misrepresentation leading to impossible physics

In fact, the mountain shadow phenomena have captured the attention of many. In *Nature*, 1886, there is an account of the shadow of Adam's Peak in Sri Lanka. Camille Flammarion in his 1872 classic *L'Atmosphere* devotes an entire chapter to extolling spectre-shadows of the European Alps. One peak, the Brocken, has become synonymous with certain people-on-mountain projections onto mists, the "Spectre of the Brocken". The shadow of Mt Fuji in Japan is famous as the *Kage-Fuji*. And so on. But none of these descriptions even hint that the shadow differed in form from the originating land-form, as Kathy had noticed.

We have since collected photographs of many mountain shadows from the world over and measured them. It turns out that (1) all mountains cast triangular shadows irrespective of the summit terrain, and (2) each mountain has a characteristic apex angle to its shadow which depends only on the ratio of the breadth of the mountain to its height above the surroundings.

So why are all mountain shadows



Whatever the shape of the summit, all mountains cast triangular shadows at low Sun For that matter, even square or rectangular blocks would cast a triangular shadow under such circumstances

The shadow of a person at low Sun mimics mountain shadows (Photo by WCL)

pyramidal? At low Sun, the outline of the mountain, as seen from its top, is projected onto the haze many tens of kilometres away. The summit outline is there, but it is so far away that it is reduced to a tiny, unresolvable profile at the shadow apex. Also, the half-degree size of the solar disc smears out detail. The general triangular shape arises entirely as a consequence of the width of the base and the height of the top Computer simulations by D. Lynch show that even a rectangular or a square block project almost triangular forms

The effects of viewing perspective and the finite size of the Sun's disc distort the shadows of people, too At low Sun, a person's shadow is all legs with the body and head reduced almost to insignificance as shown in accompanying photos.

This exercise with mountain shadows has taught me an important lesson. Remember the photograph of Kitt Peaks shadow? It hung in plain view for years without the paradox of its profile being sensed. So now, what other facts of nature surround us that we are blind to?

The summit profile which is slightly irregular becomes greatly magnified in one direction at low Sun (photo by WCL)

WILLIAM LIVINGSTON

Dr Livingston is with Kitt Peak National Observatory, USA.

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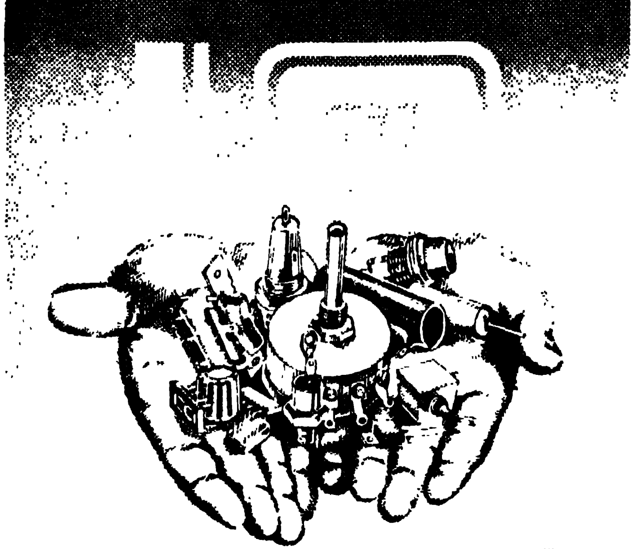

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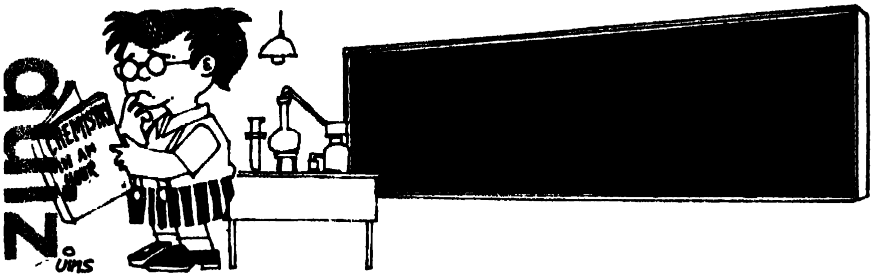
How much do you know about CHEMISTRY?



This month's quiz is on chemistry again. Listed below are 14 questions with four probable answers for each. Tick off the answer which you think is correct and turn overleaf to see how much you have improved since the last chemistry quiz (December 1979 p. 67)

1. Which one of the following statements is a precise definition of the term 'element'? A. A substance that is chemically inert. B. A substance that does not undergo any physical change. C. A substance composed entirely of atoms with the same atomic number. D. A substance which is solid at room temperature.

2. The most abundant element in the universe is: A. Hydrogen. B. Helium. C Oxygen. D. Silicon.

3. Many elements have isotopes. For example, hydrogen has three isotopes ^{1}H known as hydrogen (H), ^{2}H deuterium (D) and ^{3}H tritium (T) If in a chemical reaction one used heavy water (D_2O) instead of ordinary water, A the reaction would have proceeded in an analogous manner, as with that of ordinary water B. the reaction would not have occurred at all. C. totally unexpected products would have been formed. D. the reaction would occur at a faster rate

4. A chemist used a mass spectrograph to analyse a chlorine sample. He found three lines corresponding to the masses 70, 72 and 74 in the intensity ratio of 9:6:1. Given that chlorine molecule is diatomic and chlorine has two isotopes ^{35}Cl and ^{37}Cl, what is the isotopic composition of cholorine (ie ^{35}Cl : ^{37}Cl) A. 1:1. B. 6:1. C. 3:1. D. 9·7.

5. Two different compounds are represented by the formula C_3H_6O. We can safely conclude that A. they will have the same boiling point. B. they will have the same molecular weight. C. they will have the same molecular structure. D. they will have the same heat of combustion.

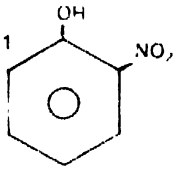
6. The hemoglobin molecule, the respiratory pigment in red blood cells, contains 0.33 per cent of iron by weight. If the molecular weight of hemoglobin is about 68,000, how many iron atoms are there in a molecule of hemoglobin (Atomic weight of iron = 56)? A.2. B.4. C.290. D.30

7. Red hot carbon will remove oxygen from cupric oxide and zinc oxide but not from magnesium oxide. Zinc will remove oxygen from cupric oxide. In which of the following are these metals in a decreasing order of reactivity? A. Zn—Mg—Cu. B. Cu – Mg – Zn. C. Zn – Cu – Mg D Mg – Zn – Cu.

8. Which one of the following elements is more likely to be used in a photocell, to generate electricity using visible light? A. Copper B. Silver C. Gold D. Cesium.

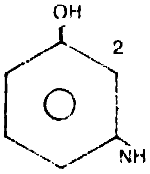
9. The molecular structure of compounds have a tremendous influence on their physical properties. Which one of the following compounds—(1) ortho-nitrophenol, (2) meta-nitrophenol, (3) para-nitrophenol—do you think will have the lowest solubility in water?
A. 1 B. 2 C 2 and 3 will have identical solubilities but less than 1, D 3

1



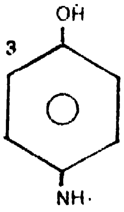
Ortho-nitrophenol

2



Meta-nitrophenol

3



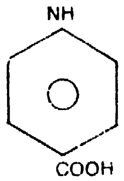
Para-nitrophenol

10. Deep sea divers use a breathing mixture of helium and oxygen, instead of air, to prevent the occurrence of the painful condition known as 'bends'. For which of the following reasons is helium used? A. Helium does not dissolve in blood but nitrogen does. B Dissolved nitrogen (in blood) is extremely toxic to cells. C. Helium being a lighter gas can easily diffuse into the lungs from the blood stream. D Helium is a lighter gas and so helps the diver to ascend rapidly

11. Which one of the following statements about the use of catalysts in chemical reactions is not true? A. Small quantities of catalysts are usually sufficient to cause a large amount of chemical change. B. Catalysts increase the rate of both forward and reverse reactions to the same extent. C. The use of a catalyst will increase the yield of the desired product. D. Catalysts will be recoverable at the end of the reaction.

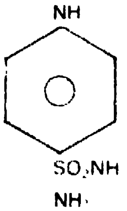
12. The term 'smog' (derived from words smoke and fog) now refers to a dense atmospheric mixture of smoke and chemical fumes, occurring in urban or highly industrialised areas. An important factor in the formation of a 'smog' is 'temperature inversion'. Temperature inversion is, A. the temperature below which water vapour in the atmosphere condenses. B. an odd atmospheric condition in which a hot layer of air covers the cooler air below C the temperature above which smog cannot be formed. D. the temperature difference between a windy day and a windless day in a city.

13. Para-amino benzoic acid has been identified as an important intermediate in the metabolism of bacteria. Which one of the following is likely to be an effective drug against bacterial infections?

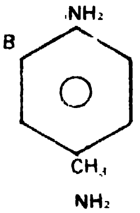


Para-amino benzoic acid

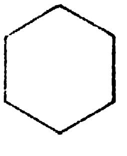
A



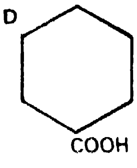
B



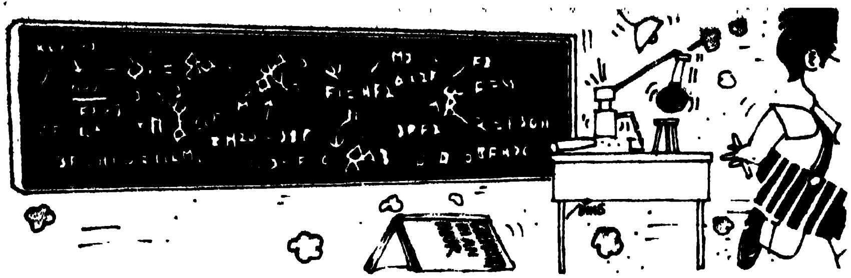
C



D



14. Atmospheric nuclear explosions release huge quantities of radioactive elements (radio nucleides) in the atmosphere. During the 'fallout', many radionucleides find their way into living organisms through drinking water and food Radioactive strontium ^{90}Sr a strong β emitter, with a half life of about 28 years, is one such radionucleide. In which tissue is ^{90}Sr likely to accumulate in humans and animals?
A Brain B. Muscles C Bone. D Blood.

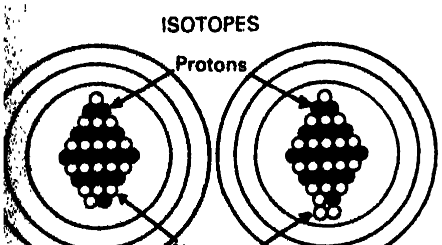


The Answers

1.—C: For centuries it was thought that atoms were immutable and indestructible and so conversion of one element into another was thought to be impossible. Prior to the discovery of the mass spectrograph there was no way to prove that an element consisted of atoms of one kind only. The discovery of isotopes and artificial nuclear transmutations of one element into another necessitated a refinement in the definition of the term element. The number of protons in the nucleus of an atom of an element, which is known as atomic number, determines its chemical nature

2.—A: Hydrogen accounts for 93 per cent of the total number of atoms and 76 per cent of the matter in the universe. Helium comes next with nearly seven per cent by number of atoms and 23 per cent by weight.

3.—A: The replacement of an atom in a molecule by its isotope does not change the chemical properties of the molecule. Replacing it by a heavier isotope, however, slightly reduces the rate of the reaction, if the reaction involves the breaking of the particular bond. When radioactive isotopes are used in place of normal atoms, it is possible to keep track of the atom during the entire chemical reaction. This tagging of molecules to trace their routes in a chemical reaction is called labelling.



The atomic number of chlorine depends on the number of protons in the nucleus. The atomic weight depends on the number of protons and neutrons In isotopes the difference is because of the difference in the number of neutrons

4.—C: The given chlorine molecules are diatomic and with the two isotopes, a chlorine molecule may be ^{35}Cl, ^{35}Cl, or ^{35}Cl, ^{37}Cl, or ^{35}Cl, ^{37}Cl. This explains the presence of mass lines 70, 72 and 74 in the mass spectrum. If you assume that you analysed 16 molecules the number of atoms of each kind will be distributed as follows:

$^{35}Cl : (9\times2 + 6\times1 + 0)/32 \doteq 24/32$
$^{37}Cl : (0 + 6\times1 + 2)/32 = 8/32$

So the isotopic ratio is 24:8, that is, 3:1.

5.—B: A chemical formula expressed in this manner cannot tell very much about the chemical or physical properties of molecules. For this, one has to know the structural formula, or the atomic arrangement in the molecule. It is the molecular structure that determines the chemical and physical properties of a compound. For example, in this case the two compounds of formulas C_2H_6O are ethyl alcohol (CH_3CH_2OH) and dimethylether (CH_3OCH_3). The two compounds have entirely different chemical properties. (See also questions 9 and 13)

6.—B: The weight of iron in a molecule of hemoglobin is 0.0033×68000. Dividing this by the atomic weight, the number of atoms of iron in one molecule of hemoglobin turns out to be

$$(0.0033 \times 68000) \div 56 \quad 4$$

7.—D: The knowledge that some elements have a greater affinity to oxygen than others has been used to extract metals from their oxide ores. In this problem it is evident that magnesium oxide is the most stable, followed by zinc oxide and cupric oxide.

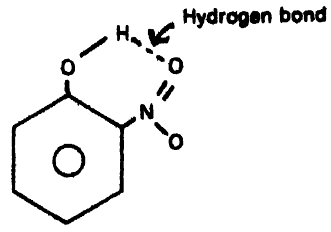
Another interesting example is the thermit welding, using the reaction:

$$Fe_2O_3 + 2Al = Al_2O_3 + 2Fe$$

This reaction is highly exothermic: the temperature rises upto 2500°C. The iron formed melts and the molten iron is used for welding.

8.—D: When electromagnetic radiation impinges on a metallic surface, the energy of the photons is absorbed by electrons in the atoms and photoelectrons are emitted, provided the photon energy is higher than a required minimum. The capacity to emit photoelectrons varies with substances but alkali metals like sodium (Na), potassium (K) and cesium (Cs) are capable of emitting photoelectrons in the visible region of the electromagnetic spectrum.

9.—A: The solubility of a substance depends upon its interaction with the solvent molecules. In the case of compound (1), the hydrogen atom in the $-OH^-$ group is able to form a weak bond with the oxygen atom of the nearby nitro group and so its interaction with the water molecules will be less. Compounds 2 and 3, on the other hand, do not have the $-NO_2$ group near the $-OH^-$ group. Therefore, hydrogen bonds with water molecules are readily formed and hence they are more soluble than 1.

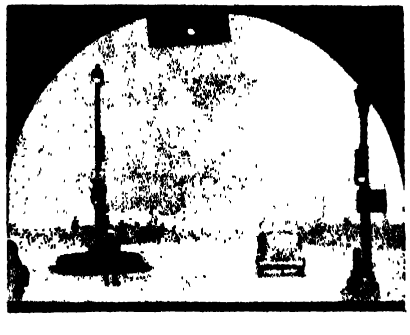


O-nitrophenol

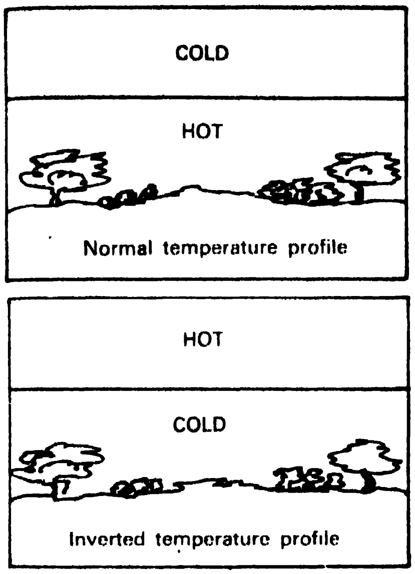
10.—C: The solubility of most gases increases with increase in pressure. Bends is a phenomenon caused by a rapid ascent through water. As the diver ascends, the external pressure on his body falls and as the pressure is reduced, the nitrogen dissolved in the blood is released and forms bubbles in the blood stream. This causes severe pain. Helium being only 0.4 times as soluble as nitrogen (a gas of low molecular weight), it is quickly eliminated from the blood stream through diffusion into the lungs reducing the danger of bends even as it bubbles.

11.—C: Consider an uncatalysed reaction $A + B = C$, under the reaction conditions (pressure, temperature and quantity of reactants), and assume that equilibrium is reached in a certain time, T_1. As a catalyst increases the rate of both forward and reverse reactions to the same extent, it can only help to attain the equilibrium condition quickly, say in time T_2 (T_2 is far less than T_1), but cannot increase the amount of C formed in the reaction which in any case will solely depend upon the amount of A and B present at the start of the reaction.

12.—B: Due to vehicular exhausts and gaseous emissions from industrial plants,

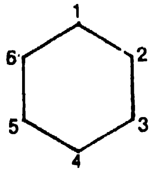


TEMPERATURE INVERSION

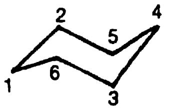


molecules like NO, NO_2 hydrocarbons, etc are released to the atmosphere. Sunlight induces photochemical reactions between these molecules to produce toxic molecules like ozone, acrolein, peroxyacetylnitrates, etc which are quite harmful. Temperature inversion causes a stagnant atmosphere in which 'smog' persists for a long time because of the absence of convection currents. (Vehicular emissions alone are estimated to be of the order of a few thousand tonnes of pollutants per day in a big city.)

13.—A: Scientists identify metabolic intermediates and synthesise compounds which are structural analogues of the metabolites. The structures (C) and (D) are non-planar whereas para-amino benzoic acid has a planar benzene ring. Compound (A) is structurally very similar to p-amino benzoic acid. Incidentally this is one of the 'sulpha drugs', sulphanilamide, effective against certain cocci infections like pneumonia. Structure (B) contains a paraffin group and cannot be effective.

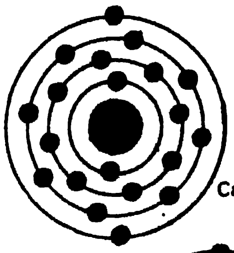


Planar ring

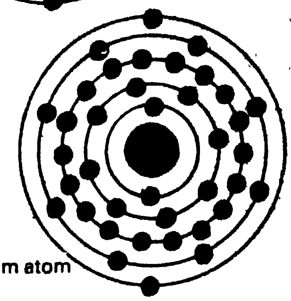


Chair-shaped ring

14.—C: The fate of the radionucleide is decided by its chemical similarity with other elements. Bone is mostly made of calcium phosphate, and ^{90}Sr (which is chemically similar to calcium), accumulates in bone. The radiation emitted by ^{90}Sr is harmful to the bone marrow, where red blood corpuscles are produced. This can lead to bone cancer and leukemia.



Calcium atom



Strontium atom

Both atoms have similar atomic configuration: 2 electrons in the outermost shell and 8 electrons in the last but one shell. This accounts for their similarity

This quiz was prepared by Mr. J. ARUNACHALAM of the Analytical Chemistry Division, Bhabha Atomic Research Centre, Bombay.

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IDEAS AND INVENTIONS

Doped plastic electrodes give lighter, efficient batteries

A RECHARGEABLE battery is an accumulator of electrical energy. The active chemicals, stored at its two electrodes, react electrochemically to produce electrical energy directly. The rechargeable battery commonly known in our country is the lead acid battery. It is very heavy and provides quite a low specific electrical power output per unit mass. A type of battery now developed by Professors Alan G. MacDiarmid and Alan J. Heeger at the University of Pennsylvania in the USA (*Chemical and Engineering News*, **59** 4, 39) is also a rechargeable battery based on organic chemicals and uses a special polymeric material for its electrodes. But it has been claimed that for the same weight it can store more electrical energy and deliver more power, leading to light, efficient, rechargeable batteries.

Electrodes for the new battery are made from stretchable films of polyacetylene doped with ions; the positive electrode is doped with the perchlorate ion (ClO_4^-) and the negative electrode with the tetra-*n*-butylammonium ion (n-Bu_4N^+). The polymeric electrode films are doped by placing them in a solution of tetra-*n*-butylammonium perchlorate (n-Bu_4NClO_4) in a propylene carbonate medium and polarising them positively (anodically) or negatively (cathodically) with respect to a metal strip. The doping, the infiltration of the ions into the material, increases the electrical conductivity of the film by a factor of 10^{12} which brings it from its normal value in the semiconductor range to one comparable to metals. Pairs of the film doped with the two ions are then used as electrodes, with the organic compound as the electrolyte.

During the charging of the battery, its electrodes further pick up the respective ions and thereby store electrical energy. When a current is now drawn from the battery, the ions are released by the electrodes into the organic electrolyte in proportion to the current drawn. Unlike in conventional lead acid or alkaline batteries, however, no electrochemical reaction occurs in this battery.

The Pennsylvania team, working with an organic battery with electrodes weighing only 4 mg with one sq cm surface, reported that the battery has an open circuit voltage of 2.5 V and could provide 22.2 mA current in a circuit of minimal resistance. This compares very well with conventional batteries of much higher weight which give 10 mA per sq cm at 2.0 V. The idea of organic batteries, therefore is well worth investigating.

The organic rechargeable battery is an extension of the principle of an electrolytic capacitor with metallic electrodes. A capacitor discharges the instantaneously stored energy once the externally applied voltage is removed. The usefulness of the organic battery developed, as an energy source or in electrical circuity, will, therefore, very much depend on its discharge characteristics. It should be capable of supplying a specific current at a fixed voltage. Its voltage should not change with time when a reasonable current is drawn from it. This would largely depend on the controlled release of the respective ions by the two electrodes without change in their potential.

Further work is necessary before this interesting device can be turned into an industrially viable proposition and a substitute for heavy lead acid batteries. This would very much depend on the technology of producing stretchable polyacetylene films with required strength at the working temperatures, which in India could vary from subzero to 45°C. Since the ions are to be picked up at all possible sites on the film, the film should have excellent swelling characteristics so that as many sites as possible (ideally, each site) can be solvated with the electrolyte enabling the ions to approach the maximum possible active sites.

Though it is abundantly available in India, storage has always been a big problem for solar energy. Such light batteries may be very useful in storing solar energy and electrical energy through a photoelectric device.

V G. GURJAR

Dr Gurjar is Assistant Professor in the Department of Chemical Engineering at the Indian Institute of Technology, Bombay.

Selenophenol can cut amine costs and reaction time

SECONDARY amines are required as intermediates in the manufacture of dyes, herbicides and rubber as accelerators, and of explosives as stabilisers. In the current methods, the amines are prepared by reducing either the isonitriles or the important intermediates—Schiff bases. In each case, starting materials have to be derived and then reduced; the reactions have to be carried out in a number of steps. The chemicals have become highly expensive and easier methods which could cut down the costs and the time of reactions are desirable.

Japanese scientists have recently come up with just such a process (*Tetrahedron letters*, **21** 35, p. 3385). They use a new reagent, selenophenol, to carry out reactions at room temperature without preparing the Schiff bases separately and show that the original ingredients themselves—the carbonyl compounds and the primary or secondary amines which can yield the Schiff bases—mixed with selenophenol in an inert atmosphere, particularly argon, can give amines with yields of 90 to 100 per cent at room temperature.

The scientists find that the molar proportions of carbonyl compounds, the amines and selenophenol must be 1:1:2.5, respectively, with one ml of chloroform as solvent per one millimole of the carbonyl compound. The reaction takes 10 minutes at room temperature. Isolating the reaction product is also simple. The final reaction mixture is treated with mineral acids, preferably hydrochloric acid. The hydrochlorides formed by the amines are easily separated and this acid mass is then neutralised with sodium carbonate to get the amine product.

The reagent was also found useful for the reductive alkylation of amines, but instead of alkyl halides, carbonyl compounds are used. This has the advantage that if alkylation of the amines is required one has simply to add the necessary carbonyl compounds in proper amounts directly to the final reaction mixture. Of course, this needs a greater amount of selenophenol.

Selenophenol is also to be preferred over the common reducing agents like formic acid, formamide, borane, borane pyridine complex, sodium borohydride, and lithium borohydride because, unlike them, it does not reduce the other reducible groups like ester, nitrile and amide groups. Chloroform as solvent, however, showed one problem—a precipitate may form in the mixture which has to be dissolved by methyl alcohol. But with other solvents like diethyl-ether, methanol or acetonitrile, either the yield drops or the reaction time exceeds 10 minutes. So far, therefore, chloroform is the best solvent for the process. Perhaps a mixed solvent will perform better, but only further experiments can provide an answer.

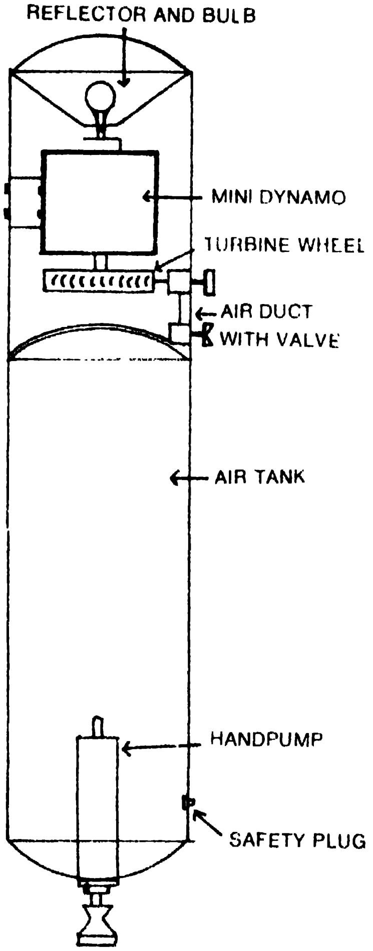
P. C. BHATTACHARYYA

Dr. Bhattacharyya teaches chemistry at Vidyasagar College, Calcutta.

Hand-pumped compressed-air torch

A HAND torch runs on very little power; typical values are of the order of a few watts. This power is provided by dry cells, which have to be replaced after they are exhausted, or rechargeable cells which consume electricity periodically. A hand torch has now been designed by Mr. K. Seshadri of Madras that dispenses with replacements and periodic consumption of electricity.

The new torch, a patent application for which is pending, uses human power. It runs on compressed air and a miniature dynamo run by an equally small turbine. A handpump compresses the air. The schematic diagram below shows the various components. The reflector and the torchlight bulb are in their usual place but the bulb is now connected to one of terminals of a miniature dynamo carrying the small turbine wheel or any other driving member capable of being driven by a thin jet of compressed air. A duct or air passage leads a jet of air from the compressed-air tank on to the turbine blades. A manually operated valve controls the jet and cuts it off when necessary. When air pressure in the reservoir falls, the required pressure can again be built up by a handpump very much like the one in a pressure stove. A safety valve is also provided to protect the reservoir from excessive pressures. When the press-button operates the valve on the air duct, the light burns and will continue to do so as long as the air tank is under sufficient pressure.



Compressed-air torch The handpump builds up pressure in the air tank which can then run a small turbine-dynamo to provide electricity to the torchlight bulb

The device is certainly a feasible proposition but whether it can become practically viable or not will depend on a number of factors. The volume of the air tank will be the first problem that will have to be tackled. On a rough calculation, at a pressure of 2 kg per sq cm. (about 2 atmospheres), a 200 cc volume of air is capable of providing energy of only 8 watt-seconds. Is it then necessary to have such an elaborate compression mechanism? Even a flywheel as light as 200 gm with a diameter of 8 cm and spinning at 6,000 rpm can deliver this amount of energy. Perhaps the problem of extra space to increase delivered energy could be tackled by increasing pressure but that will lead to leakage problems.

The air turbine will have to run at a fairly high speed in the range of 8,000 to 10,000 rpm and the bearings would have to be very carefully designed. The turbine will run slower in proportion as the pressure in the air tank falls and, along with turbine speed, generated voltage will also fall.

The best compromise solution would seem to be the use of a storage device like the nickel-cadmium rechargeable cells. Then, instead of continuous and direct hand-pumping, the nickel-cadmium cell could be recharged on the dynamo in a single stretch of pumping.

S KRISHNAMOORTHY
A S MENON

Dr Krishnamoorthy and Mr Menon are Professors in the Department of Mechanical Engineering at the Victoria Jubilee Technical Institute Bombay

Air cooled oil guns

OIL guns are used in pulverised coal fired boilers to start them up and to stabilise the flame at low loads. To protect them from the high temperature, they are retracted when not in use. Being placed between the coal nozzles, the retracting mechanism makes that part of the boiler a congested mess, besides requiring a number of imported components. A simpler system designed by the Bharat Heavy Electricals Limited, Tiruchirapalli, does away with the need for retractions and saves on imported components.

In the new design air is circulated around the gun tip through fins to improve the cooling efficiency. The guns can then be left in place and initial tests found that the gun tip was subjected to a lower temperature than the retractable type. A gun has since been installed for a 200 MW boiler and its performance confirms the design parameters. The gun's performance is also expected to be more reliable since moving parts are eliminated.

P V PARANJAPE

Mr Paranjape is on the editorial staff of SCIENCE TODAY

Composite tapes for lighter aircraft

FIBRE composites allow saving in weight, and weight is a crucial factor in all kinds of aircraft. A machine designed and developed at the National Aeronautical Laboratory, Bangalore, will manufacture unidirectional composite tape meeting international standards and useful in the fabrication of lighter helicopter blades and various fighter aircraft components.

The compact machine is divided into three zones for fibre storage, impregnation and final reel-off. In the first zone glass fibres are stored at very low temperatures and relative humidity.

In the impregnation zone, an epoxy resin-hardener mixture is forced out by a peristaltic pump, which acts much in the way our intestines handle our food.

Infrared heating lamps heat the impregnated fibre to make sure the resin wets the fibre completely.

In the reel-off zone several idlers adjust the tension and friction between pulleys and the still tacky tape, and finally wind the tape on to a spool, interspersing a thin polythene tape to separate the consecutive layers before they wind on to the spool. The winding tape increases the effective diameter of the spool and to maintain parity between the speed of incoming tape and the speed of its being wound on the tape, the reel off motor speed has to be varied accordingly.

P V.P.

Silicon from paddy husk

AMORPHOUS silica containing much less of impurities like boron, arsenic, tin etc is very highly priced and in great demand for the production of high grade silicon suitable for solar cells and many electronic devices. Now the Central Fuel Research Institute (CFRI) Dhanbad has developed two processes for extracting high grade amorphous silica from paddy husk.

Paddy husk contains about 20 to 25 per cent ash, 92 per cent of which is silica. The amorphous silica is separated only with difficulty from the normal blackish burnt ash. One technique developed at CFRI now selectively incinerates the normal ash to carbon free white ash at temperatures lower than 700°C. A second chemical technique isolates white ash directly from the paddy husk itself and also produces a substantial quantity of oxalic acid as a by-product, helping the process become more attractive and economically viable.

P V P

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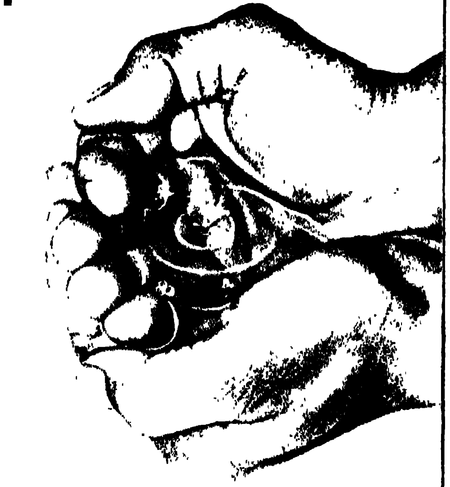

ilm made from INDOTHENE, PCL's low density polyethylene, ias proved to be a highly efficient vater barrier. At a cost that's ubstantially less than that of any other mode of lining. In addition, t's easier to handle at site and offers greater coverage during short closures. The film is vailable in widths of up to 14 metres. In any thickness you lesire. And in any quantity ou need.

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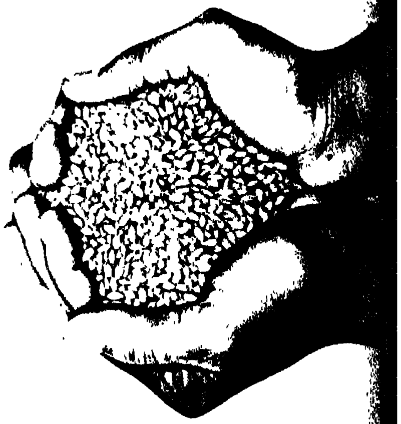
Film made from INDOTHENE has immense potential in agriculture. For example, nursery bags made of INDOTHENE film are ideal for nourishing nursery plants with the minimum amount of fertiliser and water. Being easy to handle, these nursery bags also facilitate transport and transplantation.

Another case in point is mulching, its main effect being to reduce water loss by evaporation, thus improving the quality of yield. Greenhouses, tunnels and cover bags are other examples of INDOTHENE's versatility.

INDOTHENE film keeps your foodgrain safe inside. While keeping moisture and pests outside.

The Pusa Bin is a testimony to the efficacy of INDOTHENE film. Easy to construct and inexpensive to make, the film provides a highly efficient method of foodgrain storage right at the farmers' leve Once embedded between the inner and outer walls of mud-bric bins, the film ensures that neithe insects nor moisture can get in— and also seals in a carbon dioxid rich atmosphere: just the ideal condition for the grain to stay safe for seeding and consumption. Even large structures, like CAP covers, can be made with INDOTHENE film. Because it is available in a variety of widths and thicknesse Trust IPCL to provide the perfec answer to your storage problem



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IPCL for Indothene

Will monsoon prediction be easier now?

P. K. Das

Mathematical models of the monsoon should assist in forecasting rainfall accurately

AN international Monsoon Experiment (MONEX) was conducted over the Arabian Sea, the Bay of Bengal and the adjoining areas of the Indian Ocean in the summer of 1979. It was organised by the World Meteorological Organisation (WMO) and the International Council of Scientific Unions (ICSU) as a subprogramme of a larger experiment the Global Weather Experiment. What did the experiment set out to do and what were its achievements? It should be emphasised that MONEX was not expected to provide a complete understanding of the summer monsoon. It was an one-time exercise in data collection, and its objective was to provide a data base for further research.

The monsoon is generated by the same type of conditions that produce land and sea breezes, namely, uneven heating of the land and the sea. There is a difference in the way the land and the sea respond to solar heat. The land surface warms up rapidly, because the heat that it receives remains near the surface and very little is able to penetrate more than a few centimetres through the soil. Consequently, the temperature of the land surface and that of the overlying air rises. On the other hand, solar radiation can penetrate to much greater depths in the sea because of convection in the water. This enables the Sun's energy to spread through a greater depth.

The warm air above the land rises and at some height the air flows out to the sea. To replace the rising air over land, a breeze flows in from the cooler sea to the land, which makes the coastal areas cool and pleasant on summer afternoons.

At night the land cools off much faster than the sea. Consequently, winds blow in a reverse direction from the land to the sea. This cycle of events is shown in a simplified manner in Figures 2 and 3.

These day and night phenomena have their analogues in summer and winter monsoons. In summer, the tropics receive more heat from the Sun. The heated tropical air rises and flows to the south of the heated land. There is a large return current from the sea to the land to compensate for the rising air. This is the situation in June when the Sun's heat is most intense over the semi-arid zones of northwest India and West Asia. The summer monsoon represents the return flow from the sea to the land in the form of a large daytime sea breeze. Its duration is a hundred days from the first of June to mid-September each year. Some years ago, a few scientists felt that the origin of the summer monsoon was entirely in the northern hemisphere. But, as a result of MONEX, we now know that this is not true. The trajectories of balloons that were released by France during MONEX from Seychelles and Diego Garcia indicate that the origin of the monsoon was in the southern hemisphere. In fact, one of the balloons was driven by monsoon winds from Seychelles to Burma.

Similarly, in winter, there is a flow from the land to the sea, which corresponds to the night cycle of the sea breeze. In India, this is represented by the winter monsoon. It is responsible for giving us rain over the southern parts of peninsular India in the winter season, that is, from November to March.

A question might well be asked: if it was only a difference in warming between the land and the sea, why don't we observe monsoons wherever a large piece of land is surrounded by the sea?

Fig.1 Launching a dropwindsonde

Fig.2: The sea breeze: day cycle

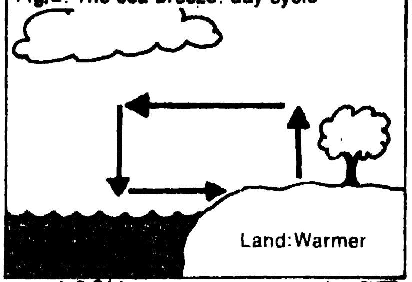
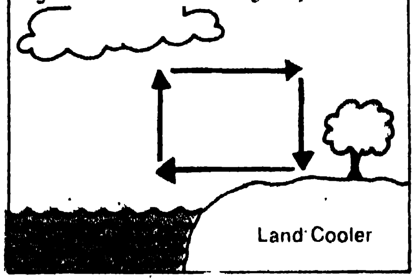


Fig.3 The sea breeze night cycle



There are two important aspects to be considered here. First, the intensity of solar radiation must be large enough to make differential heating between the land and the sea sufficiently pronounced. This only happens in the tropics. Second, there must be extensive regions of land and sea where differential heating is of sufficient duration to generate monsoonal winds. Although monsoons are known over certain regions of West Africa and Southeast Asia, the most pronounced monsoonal system is the one that affects India and adjoining parts of Asia and Africa. Despite its similarity with the sea breeze, the path of monsoonal winds is more complicated. When we consider the movement of air on a large scale, we need to take into account the rotation of the Earth and the retarding influence of friction as the air flows over the land and sea.

Forces that drive the monsoon engine

This simple description of monsoonal winds allows us to identify the important forces that drive the monsoon engine. The first, and perhaps the most important, force is concerned with solar radiation. When we consider the radiation balance of the Earth-atmosphere system, two important components stand out. One is the downward solar radiation from the Sun in the short wavelengths between 0.2 and 4.0 microns. The other is the terrestrial radiation emitted by the Earth's surface, between 200 and 330 degrees K and within the limits of 4.0 and 80.0 microns.

Radiational cooling or warming of a slab of the free atmosphere is measured by the difference between the downward solar radiation and the upward terrestrial radiation. Unfortunately, it is not simple to evaluate this difference, because both the incoming and outgoing radiation are depleted, and modified, by constituents of the atmosphere. The principal atmospheric constituents which absorb energy from solar and terrestrial radiation are water vapour, carbon dioxide, and ozone. In comparison with other atmospheric constituents, ozone, and therefore absorption by ozone, is largely confined to the stratosphere. The stratosphere is the region above 16 km in the atmosphere over Indian latitude.

Three other features are important for the monsoon. The first is the distribution of clouds. Clouds not only reflect solar radiation, but also emit longwave radiation like the Earth's surface. Second, a good part of the solar radiation is scattered by large aerosols and dust particles. This is important for the semi-arid parts of northwest India and the countries of West Asia, because the atmosphere carries a heavy dustload over these regions. It has been estimated that for every square mile of north India, there are about 5.5 tonnes of fine dust particles suspended in the air. Last, the reflective properties of the land and the sea have an important feedback on the radiation balance. The reflecting power of the Earth's surface is known as its albedo, and it varies widely over the entire monsoon regime. Generally, desert sands or snow-covered mountains are much more reflective than wet soil or the sea.

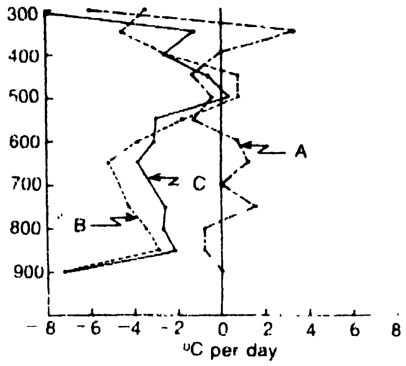


Fig.4 Vertical distribution of heating rates in °C per day over Saudi Arabia This is for a morning ascent at 8 00 A.M local time on 12 May 1979 A—Short wave. B—Long wave C—Net heating rate

The figures in the ordinate represent pressure in millibars (mb) Note that the net profile (C) shows a cooling between 900 and 300 mb (1 0 to 9 0 km)

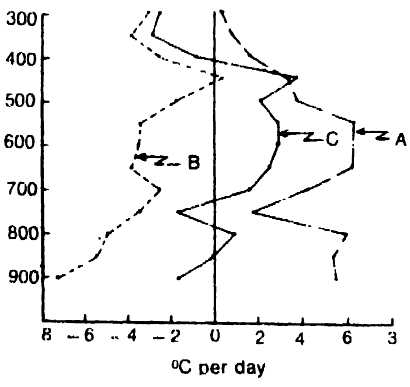


Fig.5. Same as in figure 4 This represents an afternoon ascent at 2.00 PM local time on 9 May, 1979 The figures on the ordinate represent pressure in millibars (mb). while the abscissa provides heating rates in °C per day The net profile (C) shows a warming between 750 and 400 mb (2 5 to 7.5 km).

For many years, the balance between the incoming and the outgoing radiation was imperfectly understood. But, during MONEX we had observations of the incoming and outgoing radiation by instrumented aircraft over different layers of the atmosphere. Figures 4 and 5 show two profiles of radiative temperature changes over Saudi Arabia as observed by US aircraft. The first is a typical morning profile, while the second refers to the afternoon. One

Observation techniques

MANY observational techniques of MONEX were novel, to which Indian scientists were exposed for the first time. This experience will be useful for future work.

In May 1979, as many as 52 research ships were deployed over the tropical oceans between latitudes 10°N and 10°S, while 104 aircraft missions were successfully completed over different parts of the Pacific, the Atlantic and the Indian Ocean during the same period.

The main contributions to MONEX were: five research ships from the USSR; three civilian research aircraft from the USA; four research ships and one aircraft from India; and one research ship and a programme for monitoring winds with constant level balloons from France. In addition, the US moved one of its geostationary satellites GOES Indian Ocean—to a location on the equator at 60°E to cover the MONEX region. GOES is an acronym for a Geostationary Operational Environmental Satellite, and the Indian Ocean was its location during MONEX Now that MONEX is over, it has been moved to another location. Cloud clusters that were recorded by this satellite were beamed towards Bombay by METEOSAT another geostationary satellite launched by the European Space Research Agency. By tracing clouds, one could derive a complete picture of the monsoon winds.

The experiment lasted from 1 May to 31 August 1979. In these 123 days, 46 scientific missions were flown by US aircraft for the Arabian Sea and the Bay of Bengal phases of the experiment. The aircraft were equipped with dropwindsondes. This is an instrument package which is released from the aircraft. A tiny parachute attached to this package enables it to descend slowly. The instruments record temperatures and winds over different layers of the atmosphere during the descent. Figure 1 shows the release of a dropwindsonde during MONEX.

Research vessels from the USSR formed moving polygons over different parts of the Indian Ocean, the Arabian Sea and the Bay of Bengal. They provided us with valuable observations by probing the atmosphere with balloon-borne equipment and meteorological rockets.

For the first time, Indian ships were equipped for measuring the upper winds. This was achieved with the help of omegasondes. An omegasonde is a balloon-borne equipment package. It uses an international navigation system based on the intersection of radio beams on very low frequencies to track the path of a balloon. The movements of the balloon provide a measure of the speed and direction of upper winds.

An Indian aircraft was used for the first time in India for conventional meteorological observations over the monsoon regime. The equipment on the aircraft were assembled in a short time and, despite difficulties, many observations were recorded of the structure of low pressure system that generates rainfall.

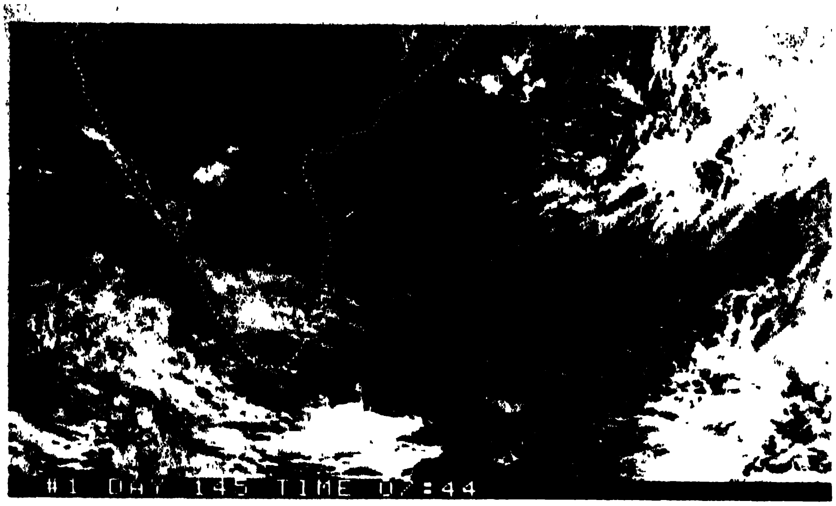
Important contributions were made by the Indian Space Research Organisation (ISRO) towards MONEX Indian scientists were able to begin work on an indigenous version of the omegasonde, which will be soon used on the *Gaveshani*, a research vessel belonging to the National Institute of Oceanography.

An International MONEX Management Centre (IMMC) was set up in New Delhi to supervise the monsoon experiment. A number of scientists from different countries worked at this centre for research on monsoon dynamics.

The centre has published 14 volumes of pre-checked MONEX data. The final form of the data are likely to be ready by the end of this year.

After the field phase of the experiment, Indian scientists were deputed to different monsoon lands to personally collect the data that were recorded by various national meteorological services. As of today, 45 countries have sent their data to the IMMC. They are now being checked for internal consistency and uniformity before they are published. The entire volume will consist of over a hundred million coded characters. Computer programmes have been devised by Indian scientists to convert these characters into processed meteorological information.

P. K. D.



of them shows a general cooling of the atmosphere from 900 to 300 mb (approximately from 1 to 9 km), while the other is indicative of a warming atmosphere from 750 to 400 mb, that is, from 2.5 to 7.5 km. In addition, the radiation measurements over India revealed an interesting feature of the outgoing terrestrial radiation. An inverse relationship was discovered between the intensity of outgoing radiation between the lower atmosphere (surface to 6 km) and the middle atmosphere (6 to 12 km). Clearly, there are wide variations in the radiation balance, and one is tempted to ask: what is the impact of such variations on monsoon winds?

Mountains constitute another force that drives the monsoon engine. Large mountains tend to deflect the wind, so that they flow round them instead of over them. There are several mountain ranges, such as the Ethiopian mountains, the mountains of Burma, the Western Ghats and, the largest in the world, the Himalayas, which come in the path of the monsoon winds. They not only help to deflect the winds in certain directions but, what appears to be more important, guide rain-bearing systems, such as depressions, along certain preferred tracks. The exact mechanism by which this is brought about is not well understood.

The third component is the troughs and depressions. The monsoon is not un-interrupted rainfall for hundred days. There are spells of heavy rain over the Indo-Gangetic plains, followed by periods of lean rainfall or "breaks" in the monsoon. The sequence of heavy and lean rainfall is closely associated with the north-south movement of an elongated zone of low pressure, which runs parallel to the southern periphery of the Himalayas. Meteorologists call it the monsoon trough. In Figure 6 we show its normal position in the monsoon month of July. The northward shift of the monsoon trough leads to the cessation of rains over north and central India. During the period of "break", the rain belt moves abruptly to the extreme northeastern parts of the country, while the rest of the country remains dry.

Of the other principal meteorological systems, which cause short period variations in rain, mention may be made of depressions in the north Bay of Bengal; mid-tropospheric low pressure systems, located between 2 and 6 km, off Gujarat; and off-shore vortices off the west coast of India. MONEX gave us data on the wind and thermal structure of these systems. In particular, the Indian aircraft data showed substantial temperature variations within these systems. **The existence of such large temperature gradients was not known before.**

How do these rain-bearing systems help to drive the monsoon engine? These systems generate rain which, in turn, releases large amounts of latent heat into the atmosphere. This latent heat helps to drive the monsoon circulation by generating wave-like disturbances that produce kinetic energy of motion. A striking feature of the 1979 monsoon was the sudden and abrupt increase in the kinetic energy of the atmosphere at the time of the monsoon onset over Kerala. Scientists are now considering several mechanisms which might produce the observed increase in kinetic energy.

Some scientists believe the onset of the monsoon and the formation of depressions or mid-tropospheric low pressure systems are manifestations of atmospheric instability. The conditions that enable an atmospheric disturbance, such as a travelling wave, to grow and transform itself into a large circular vortex, which has the structure of a depression, are now known. In broad terms, these conditions place certain constraints on the horizontal and vertical variation in the strength of prevailing winds. If the horizontal and vertical wind gradients exceed certain critical values, then a travelling disturbance would have the wherewithal to extract energy from its surrounding environment, and grow into a circular vortex. But, while we know, broadly, the conditions that are necessary for instability, we do not know whether they are sufficient by themselves

Meteorological scientists have

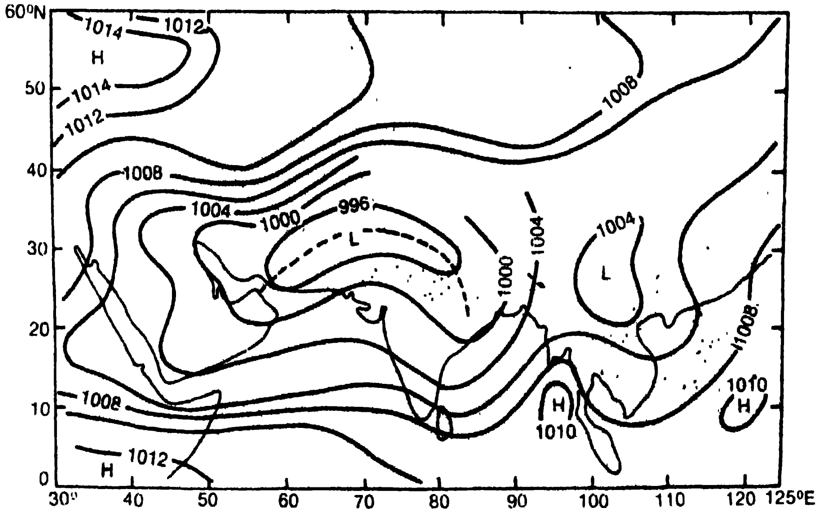


Fig. 6 · Normal position of the monsoon trough in July. Full lines represent lines of equal pressure (isobars). Pressures are expressed in millibars (mb). The dotted lines show the normal position of the trough axis. Areas of low and high pressure are indicated by "L" and "H" respectively. Latitudes are indicated on the ordinate, while longitudes are given on the abscissa

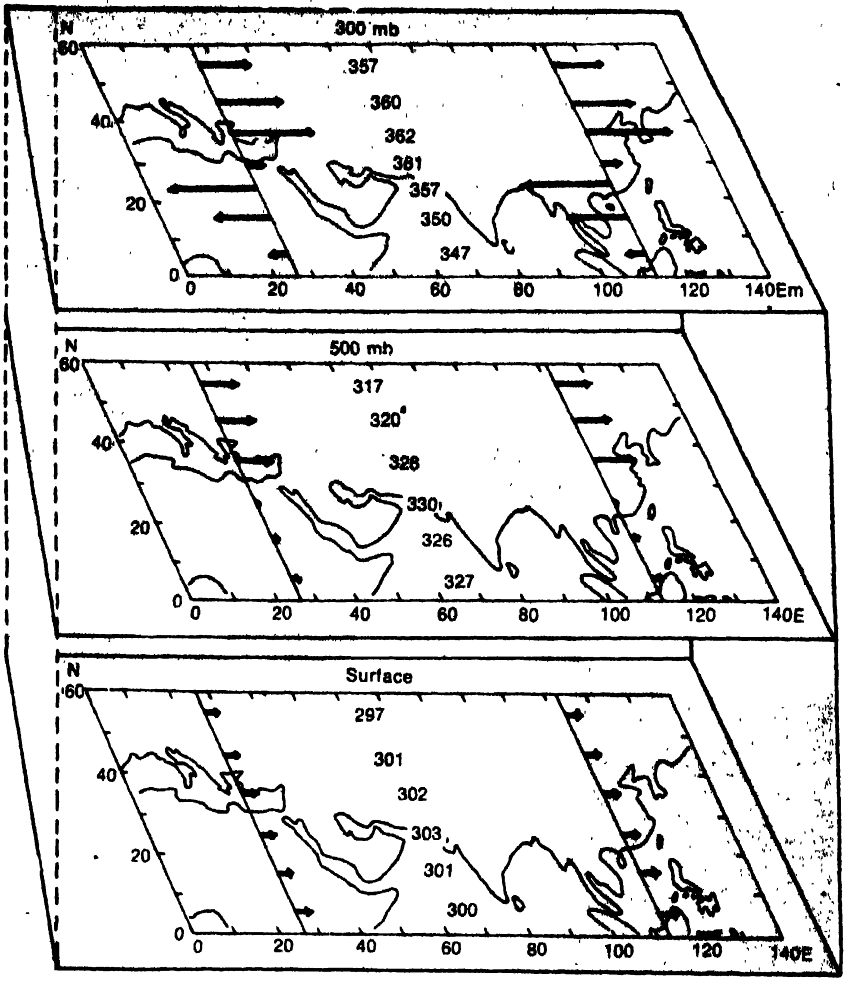


Fig 7 Idealised initial state, at three pressure levels of the atmosphere (surface 500 and 300 mb) Arrows indicate wind direction, while figures represent normal values of temperature (°K). The scale of wind speed is indicated by an arrow at the bottom in metres per second Note that initially we assume winds flowing from west to east upto 500 mb Southward of 25°N, the direction of wind flow is reversed at the highest level (300 mb) The reversal of wind direction is a typical feature of monsoon winds

claimed that a decrease in the vector difference between winds in the upper and lower atmosphere is a condition for the formation of monsoon depressions in the Bay of Bengal. It is easy to see why this is so, because a reduction in the vector wind difference favours the formation of clouds and vertical convection. We can thus state that this is one of the necessary conditions for depression formation. But can we claim that it is sufficient? Clearly, we cannot, because there several other factors are also involved, such as the vertical and horizontal temperature profiles of the atmosphere. Depending on which factor is predominant, a depression could form even when there was no marked decrease in vector winds

A word of caution would be in order, therefore. Many scientists tend to pick upon stray features and lay claim to a "discovery", when a complete explanation needs a demonstration of not only the necessity but also the sufficiency of an observed relationship. An example is concerned with a decrease in the vector difference between upper and lower tropospheric winds prior to the formation of a depression. A careful examination reveals that while this condition is necessary, it is not sufficient, because depressions do not form even when this condition is satisfied. Hence its predictive value is rather limited.

Air-sea interactions are another force Earlier experiments had identified the existence of a narrow stream of strong winds at low levels off the coast of East Africa. This is now known as the Somali jet. There seems to be a coupling mechanism between the low level Somali jet and a zone of coastal upwelling off Somalia. Oceanographic observations during MONEX indicated that cells of extremely cold water tend to move along the coast from the south to the north. They suggest the propagation of wave-like disturbances on the surface waters of the sea. A cold sea tends to extract heat from the overlying atmosphere, while a warm sea, off the west coast of India, tends to supply heat to the air above. This process of exchange must influence the air as it traverses the Arabian Sea before striking the Indian coastline.

Indeed, MONEX observations reveal a temperature inversion—an atmospheric layer where the temperature rises instead of falling with height—over the western sectors of the Arabian Sea. This tends to inhibit cloud formation but as we approach the Indian coast the inversion is gradually wiped out, and strong convective activity becomes a prominent feature.

Mathematical models

A powerful tool is now beginning to emerge for understanding the behaviour of the monsoon. This is based on mathematical models to simulate the monsoon. These models use the law that govern the motion of a fluid, such as air, when it is subjected to external forces. The response of the fluid to different forms of heat exchange, that is, between the land or sea and the overlying air, or through the release of latent heat, is incorporated in the model by the first law of thermodynamics. The first law of thermodynamics is essentially a statement of conservation of energy. What the model asserts is that any variation in the energy of a parcel of air that may be brought about by a transformation during its traverse over land and sea must be equal to what it receives from its environment. If, for example, through the conversion of water vapour to rain a certain amount of latent heat is released in the atmosphere, the model will transform this

What did MONEX reveal?

SOME years ago there was a controversy about the origin of the monsoon. Many scientists felt that there was very little by way of movement of air from the southern to the northern hemisphere. The observations during MONEX did not support this view. In fact, the trajectories of balloons that were released by France from Diego Garcia and from Seychelles in the southern hemisphere clearly showed that they were driven by the monsoon winds right across the equator towards the Indian coastline. These balloons had a built-in device, to ensure that they always flew at a constant altitude. One of the balloons released from Seychelles could be traced right up to Burma.

The main observational findings.

Onset of monsoon: The onset of the monsoon in 1979 was delayed by over ten days. MONEX data suggest that this was caused by a pronounced clockwise circulation of winds over the southern parts of the Arabian Sea. This made the winds blow parallel to the Indian coastline in a north-south direction. In a normal monsoon, the winds should have been hitting the coast in a perpendicular direction blowing from the west to the east. The data reveal that, simultaneously with the onset, there was a sudden and abrupt increase in the kinetic energy of atmospheric winds.

Rain-bearing systems: The main rain-bearing systems of the monsoon are depressions in the north Bay of Bengal, middle atmospheric low pressure system over Gujarat, and off-shore vortices. The data recorded by Indian aircraft showed substantial horizontal temperature variations within these systems. The existence of such large temperature variations was not known before.

Vertical distribution of radiative warming: The vertical distribution of radiative warming was measured for the first time by research aircraft over several sectors of the monsoon regime. The data suggest that rapid and frequent changes occur in the radiation profile during the monsoon, depending on the distribution of clouds. The terrestrial outgoing long-wave radiation was measured over several Indian stations by radiometersondes. The data reveal an inverse relationship in the intensity of outgoing radiation between the lower atmosphere (surface to 6 km) and the middle atmosphere (6 to 12 km).

Upwelling off the coast of Somalia: Earlier experiments had identified a region of coastal upwelling off the coast of Somalia in East Africa. Oceanographic observations during MONEX indicated that regions of extreme cold water tend to move from the south to the north in the form of small cells. They suggest the propagation of wave-like disturbances on the surface waters of the sea. The coupling mechanism between a low-level jet stream off the East African coastline and the movement of such waves is currently being investigated.

P. K. D.

additional energy into the energy of motion. The advantage of a model is that it enables one to perform control experiments on the atmosphere. One could study, for example, what would happen to monsoon rains if there was largescale denudation of forests, or if the Arabian Sea was much warmer than usual.

The aim is to construct an artificial monsoon—a model—which is sufficiently close to the natural monsoon. Unlike the natural monsoon, however, one can deliberately change the forces that control the model monsoon, such as solar radiation and topography. By this means scientists are utilising MONEX data to gain an insight into the physics of the monsoon.

In India, a beginning has been made in the study of the impact of topography and solar radiation. A model has been designed which starts with an idealised initial state (Fig. 7). This is a system of winds flowing from the west to the east, but with a reversal in the direction of flow at around 5 km. This reversal is a common feature of the Indian monsoon. Temperatures that are typical of the monsoon atmosphere are shown in this figure. We now disturb the initial state by inserting mountain barriers. The response of the model is then computed on a computer by integrating a system of mathematical equations. After eight days of simulated time, the model response obtained is shown in Fig. 8. The interesting feature to note is that the mechanical effect of mountains is not sufficient to generate a monsoon trough. Next, in addition to mountains, we add (i) downward solar radiation, (ii) soil reflectivity, (iii) reflected radiation from clouds, and (iv) the vertical profiles measured over Saudi Arabia. The model responses after eight days are shown in Figs. 9 and 10. The first figure refers to the morning radiation profile, while the second one corresponds to the afternoon.

Two interesting features stand out: first, we see that by including radiation in our model, we can reproduce the monsoon trough and, second, the orientation of the trough is sensitive to the radiation profile over Saudi Arabia. This is an interesting result because it suggests that better prediction of short-term (five to seven days) rainfall variation might be possible if we monitor radiation profiles more frequently.

Model development with MONEX data is still in its early stages though the results must be interpreted with caution, because there are inherent model limitations. Some of these limitations are mathematical, because analytical solutions to the com-

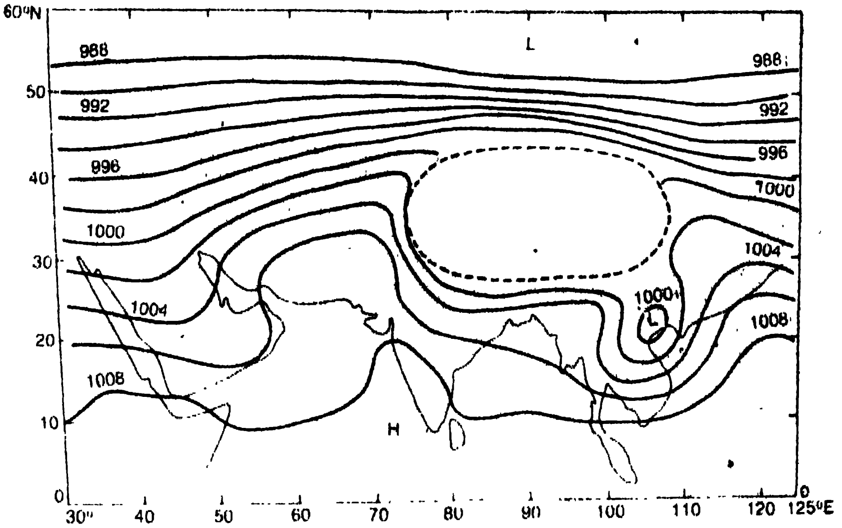


Fig.8 Model response after eight days with only mountains. Full lines represent isobars, while figures represent pressure in mb The dotted line indicates the Himalayan barrier. Areas of low and high pressure are indicated by "L" and "H" respectively. Note the formation of a low pressure zone eastwards off north Burma. This resembles the low pressure area off north Burma in figure 6, but the model fails to reproduce the monsoon trough of figure 6

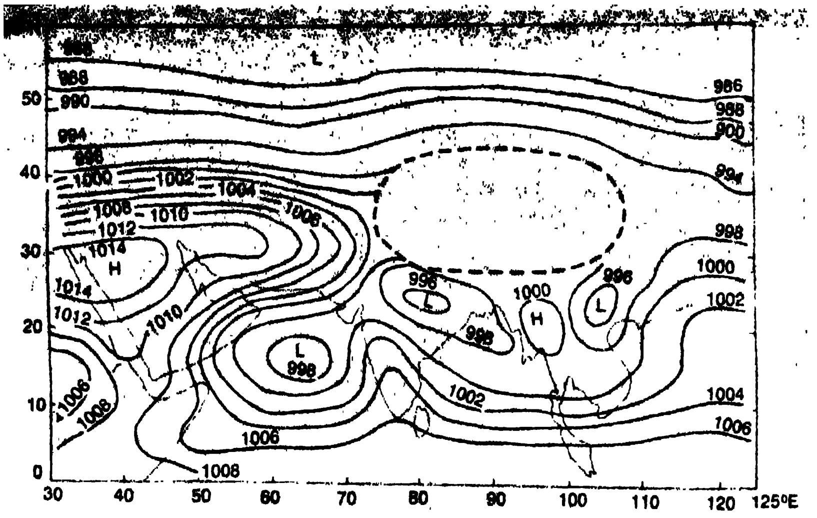


Fig. 9: Model response after eight days with not only mountains, but also the morning heating profile over Saudi Arabia shown in figure 4. Note that the model is now able to reproduce the monsoon trough shown in figure 6 The low off north Burma is also evident

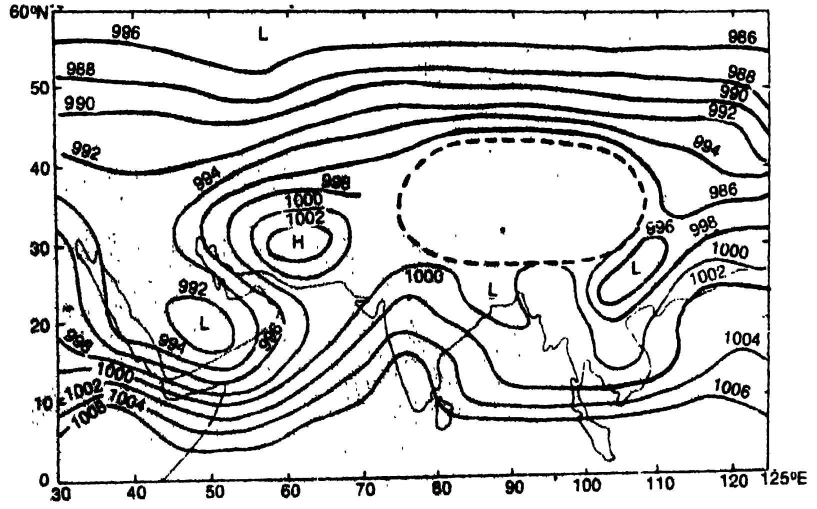


Fig.10. Model response after eight days with not only mountains but also the afternoon heating profile over Saudi Arabia shown in figure 5 Note that the monsoon trough is now very weak. The low off north Burma is displaced far too the east

plex system of equations which govern atmospheric motion are not possible. The model tries to find numerical solutions to these equations by approximations. In view of the limited computing facilities the resolution of the model needs improvement, and many phenomena, on smaller space scales, are ignored by the model. Despite difficulties of this nature, it is reasonably certain that progress towards an understanding of the dominant factors of the monsoon will require new models, with increasing physical and mathematical complexity. When questions are raised about the wisdom of large scientific experiments, such as MONEX, it is well to remember that without MONEX data we could not have constructed meaningful models. And, without modelling experiments, we can hardly hope to improve our understanding and prediction of the monsoon rain.

Long-range prediction and inter-annual variability

The 1979 monsoon was an abnormal one; rains stopped suddenly around mid-August, almost a month before the normal date of monsoon withdrawal. The arrival of the monsoon was also delayed by nearly ten days over Kerala. MONEX was thus instrumental in focusing attention on deficient monsoon conditions.

This leads one to the question of inter-annual variability of monsoon rain. Why is rainfall plentiful in some years and deficient in others? Today, we do not have a really satisfactory answer, but several possibilities are being explored.

One possible avenue lies in the detection of meaningful periodicities in monsoon rain. But so far only one oscillation has been detected which appears to occur with some regularity. This is a 26-month cycle, quasi-biennial, in the strength of stratospheric winds over the tropics. Attempts are being made to associate the ascending and descending phases of this cycle with the monsoon's performance, but firm results are as yet difficult to discern.

Meteorological teleconnections are now attracting attention. By this we mean statistical associations, in space and time, between widely separated events. Sir Gilbert Walker postulated in 1924 a "southern oscillation". This suggests an inverse correlation between the behaviour of

How hard will it rain this year?

ACCORDING to the long-range forecast worked out by the Meteorological Department, there is a four to one chance that the June-September monsoon rainfall will be favourable, a few per cent above normal, this year.

Forecasts of seasonal rainfall need not be worked out in detail for all regions; they are important where the rainfall varies considerably from year to year. All such areas in India are grouped into two regions—the Peninsula and Northwest India. The Peninsula is taken to comprise Maharashtra, Gujarat and Madhya Pradesh, coastal Andhra Pradesh, Telangana (in Andhra Pradesh), interior Karnataka (north), and coastal Karnataka, excluding South Kanara district. The other region, Northwest India, is taken to comprise Jammu and Kashmir, western Uttar Pradesh, Haryana, Punjab, Himachal Pradesh, Delhi, Chandigarh and Rajasthan.

The statistical method developed shows that the 1981 monsoon rainfall in India will lie between 97 per cent and 112 per cent of the normal in the Peninsula and between 97 per cent and 117 per cent in Northwest India. The method statistically correlates monsoon rainfall and some preceding meteorological features in various parts of the world. This forecast was based on the equatorial and the South American pressures in April, Indian upper air data for April and Indian surface temperatures.

Another forecast uses auto-regressive integrated moving averages (ARIMA). The first ARIMA forecast also suggests a likely excess over normal but of 14 per cent for the Peninsula and two per cent for Northwest India. Another ARIMA forecast will follow by the end of June (and the final one by the end of July) which will take into account the latest data and put out a modified, more accurate forecast. Meanwhile, we can duly expect a normal rainfall.

P.K.D.

the atmosphere over the eastern Pacific and India, Indonesia and the tropical parts of Australia. Some evidence has been recently produced to support this association, but its cause is still not understood. One possible mechanism might be the existence of cells in atmospheric circulation which are oriented in an east-west direction. They could be in the form of largescale standing waves, representing longitudinal perturbations. What excites these perturbations is not yet known.

We started with the question, what did MONEX set out to do and what did it achieve? Looking back on the past couple of years, we see many positive results emerging from this experiment. New observational techniques, such as omegasondes, were developed and used for the first time over India. The frequency of routine conventional observations was increased and data were obtained for the first time on several new features, such as radiation. New platforms such as aircraft and geostationary satellites were used.

Indian scientists were able to devise computer programmes for handling very large volumes of data. Quality control checks were designed, and the data were put in a format suitable for research.

A beginning was made towards utilising the data for monsoon models. Diagnostic studies with these models are now helping us to ascertain what are the dominant features that control monsoon rain. More research will be needed in the next few years towards developing better models, with more built-in physics and input data. It is essential for such research to continue, if we are to improve our prediction capability, especially on larger scales of time.

The importance of monsoon prediction may be realised when we note that, with a good monsoon, our current annual cereal production is around 135 million tonnes. To maintain the current level of nutrition, we will need to achieve a figure around 200 million tonnes around AD 2000. The task ahead is going to be difficult, but not impossible. It will become easier if we could anticipate a spell of deficient rain or a lean monsoon. For this purpose, more diagnostic studies are needed.

Lastly, MONEX provided us with a good example of international collaboration in which India played a leading role. Within the next few years India will launch an ambitious programme in space meteorology. It is not unreasonable to expect that the benefits of our programme in space could pave the way for yet another MONEX, or a series of further experiments on different aspects of the monsoon.

Dr. Das is Director-General of Meteorology, and Director of the International MONEX Management Centre in New Delhi. He specialises in meteorological dynamics, numerical weather prediction and mathematical modelling in 1963, he was awarded a gold medal by the Government of India for his paper "Mountain Waves" Dr. Das is an elected member of a board of 12 scientists for guiding the scientific activities of the Global Atmospheric Research Programme (GARP) of which MONEX was a subprogramme. He is also an elected member of the Executive Committee of the World Meteorological Organisation.

Recommends Reading: 1. *The Monsoon Experiment*, World Meteorological Organisation, GARP Publication Series No.18, Geneva, 1976. 2. *Summer Monex Field Phase Report*, World Meteorological Organisation, FGGE Operations Report vol 8, Geneva, 1981 3. Das P. K. Numerical Simulation of the Indian Monsoon, *Proceedings of the Indian Academy of Sciences*, **89**, 2, 159, 1980. 4. *Proceedings of the National Symposium on Early Results of the Monsoon Experiment* (March 9-11, 1981), India Meteorological Department, New Delhi

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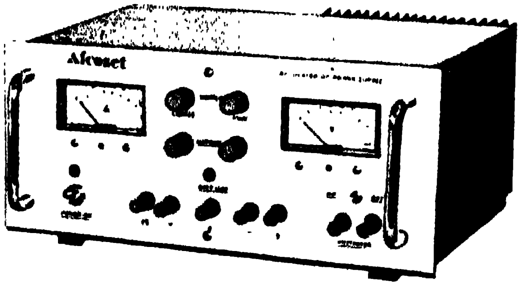

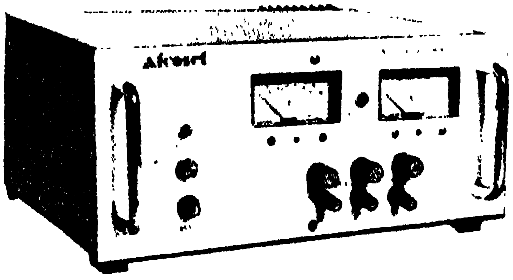

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The Nuclear Disaster That Wasn't Science Fiction

Nuclear disaster in the Urals by Zhores A. Medvedev (Translated from Russian by George Saunders), Vintage Books, New York, 1980, 215 pp. $2.95

IN 1976-77, Dr. Zhores A. Medvedev, a dissident Soviet scientist now living in England, referred to the Urals nuclear disaster in his article in the *New Scientist* of 4 November, 1976. His claim that hundreds of people died in the nuclear disaster in the USSR, in 1958, was initially dismissed as "pure science fiction" by the Western nuclear pundits. Medvedev was variously accused of "fabrication" and "sensationalism". But as a man of science he took up the challenge to verify his conclusions.

By writing this book, Medvedev has not only restored his scientific credibility but has also helped those who are concerned with stopping the nuclear contamination of the environment with which humanity must be able to live for millions of years to come. Whereas our politicians and the nuclear vested interests think in terms of one or two decades, the nuclear energy policy-makers must weigh their decisions in terms of several centuries. Being a biologist and geneticist, Medvedev thinks "about the future from the point of view of evolution, constructing future models with reference to millions of generations" to come. The book is based on this scientific commitment.

Sir John Hill, then the chairman of the U K Atomic Energy Authority, had, described Medvedev's *New Scientist* article as "rubbish" and "a figment of the imagination". What Medvedev knew from memory by working in the USSR, gave him clues where to look for the proofs. He sieved the data from various scientific journals published on the biological and genetic effects of "hypothetical" nuclear disaster in that region by the Soviet scientists. These refer to radioactive migratory birds and bees, living and non-living matter spread all over—in the air, on the surface and in waters and minerals of the Urals region. For example, there are scientific papers on the effect of radioactive contamination on various species of ticks and mites of the region. And the migration of strontium and calcium was traced from the soil and soil animals to flying insects, rodents, frogs, large mammals (ungulates, without the species being indicated), and birds (again, without indication of species). For each group of animals, summary figures were given for the accumulation of strontium-90 and calcium, with the biomass and the isotope quantity being calculated per hectare.

Medvedev observed that since ungulates (such as roe deer and reindeer) were included in the experiments, it is evident that the total size of the contaminated zone was rather large. Besides CIA reports, there are confirmed road-sign warnings to drivers not to stop for "the next 30 kilometres and drive through at maximum speed" at about 100 kilometres from Sverdlovsk, that the whole country was (is) exceedingly "hot" and that hundreds of square kilometres had been laid waste, and unproductive for hundreds of years.

DHIRENDRA SHARMA

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Marine ecology

A text book of marine ecology by N. Balakrishnan Nair and D M Thampy, Macmillan India, 1980, 352 pp. Rs 41.50

ABOUT two-thirds of our planet's surface is occupied by the hydrosphere. For centuries, man has explored the ocean, exploited its great wealth, and used it for transportation

With the population explosion and the shortages of food and energy, ocean technology and its exploitation has been put-first on the priority list in national development. This has also led to understanding of the interactions of millions of diverse plant and animal species with their environmental matrices. This science has now been designated as "marine ecology" There is vast data on the marine ecology of the major continents and their surrounding oceans, but very little about that of our own subcontinent.

During the early decades of the present century, the marine ecology studies, which generally included taxonomy and distribution of the flora and fauna of Indian waters, were initiated by surgeon-naturalists attached to IMS ships (1881-1926) and by other British scientists, the pioneers being Alcock, Annandale, Day Fauvel, Gardiner, Gravely, Hornell, Kemp, and Sewell. The efforts of these early workers, however, were rather fragmentary. With Independence, the development of marine sciences was given top priority and many universities, especially in the southern belt, introduced courses in marine biology and oceanography at post-graduate levels. The students had to follow the text books written by British, American and other European marine scientists. There was a lack of such books written by Indian scientists.

The book is written in a simple and lucid language keeping in mind the requirements of graduate and post-graduate students. The text adequately covers the physical, chemical and other abiotic environmental factors, and their interrelations within the communities. This is followed by the detailed ecology of the sea-floor, benthic and pelagic regimes along with the communities inhabitating it. The emphasis is on the ecology of fouling organisms, Prof. Nair being an acknowledged authority on the biology of these organisms. Similarly, discussing the origin and classification of estuaries in general, the ecology of major Indian estuaries (for example, the Mahanadi, Godavari, Hooghly-Matlah, Cauvery, Adayar and Vellar) has been dealt in detail. The organic production, food cycles, fishery and mineral resources, marine culture of algae and shellfish, population and instruments and techniques take up the rest of the book.

One feels that marine pollution and its effects should have been elaborated upon, since this is of great importance in the present industrial revolution in maintaining the balance and health of the marine environments. There is very little information, however, on the significance of bacterial flora, which forms a basic link in the marine ecosystem and modifies many ecological parameters. Similarly, inclusion of new disciplines—radioecology and chemoecology—which have emerged during the nuclear decades would have updated the text.

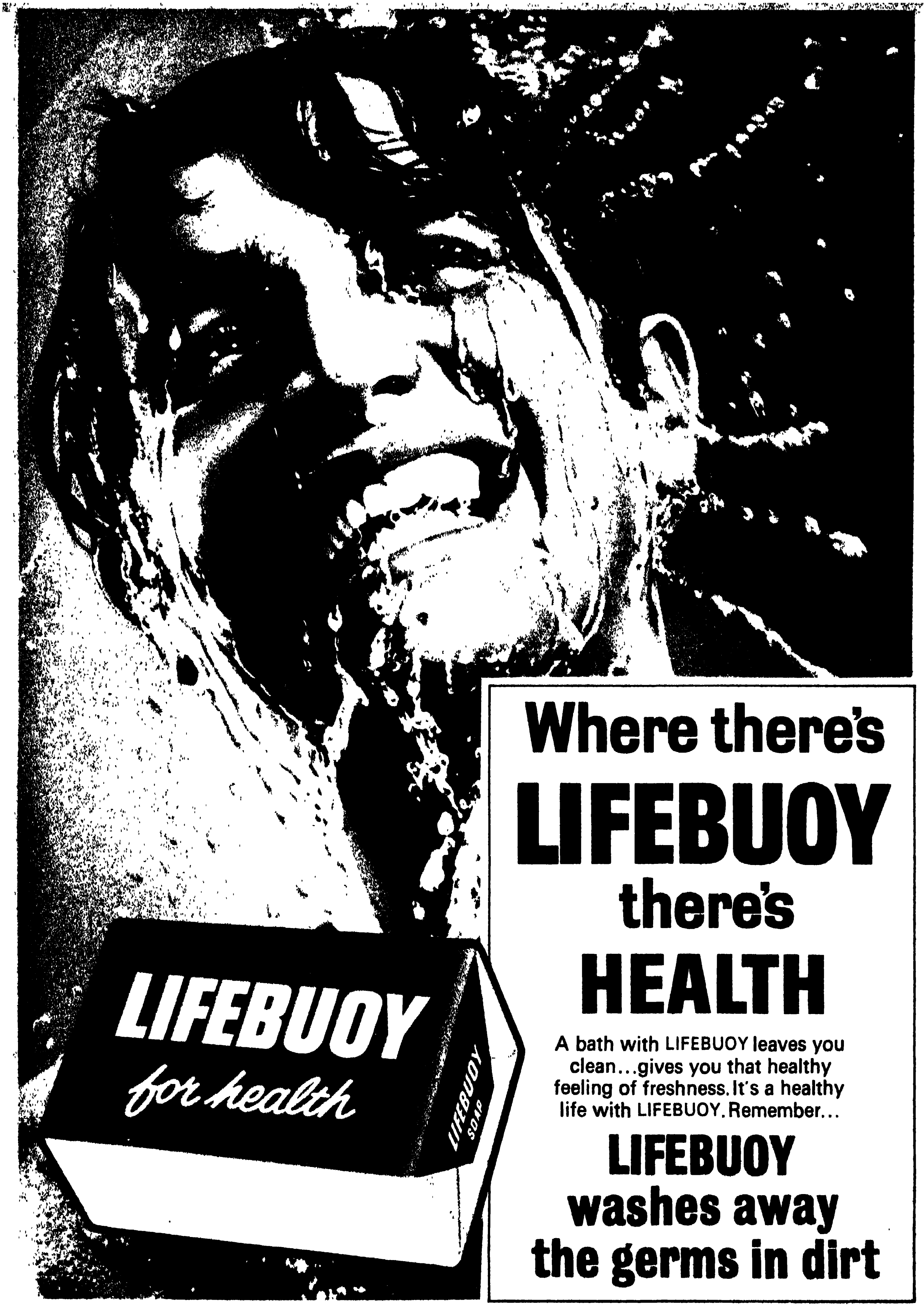
The majority of works quoted on physico-chemical environmental factors are quite old; the inclusion of the latest references/would have enlightened and introduced the students to the new concepts and technologies adopted. Similarly, the historical review of the work carried out on the Indian Ocean by earlier British workers should have been highlighted. Also, the works in the field by present-day Indian marine scientists should have been liberally reviewed. A list of premier institutes and their achievements in ocean studies would have benefited students.

The publishers should have taken care to avoid shortcomings like spelling mistakes and poor printing. Many illustrations are poorly reproduced and lack detail. In a text book like this, the printing of figures on folded pages is undesirable. The printing of two-tone photographs on art paper would have increased their clarity.

In general, the book is recommended both for students and research workers.

B. PATEL

Dr. Patel is with the Health Physics Division, Bhabha Atomic Research Centre, Bombay



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What APPLE means

Pramod Kumar

K. S. Karnik

India makes her bold entry into the field of satellite telecommunications

THE sky over India has a new satellite—the Ariane Passenger Payload Experiment or the APPLE spacecraft. The spacecraft, designed and developed by the Indian Space Research Organisation (ISRO), was put into orbit as a "passenger" on the third developmental flight of the Ariane rocket developed by the European Space Agency (ESA) from the Kourou Space Centre in French Guiana last month.

APPLE is an important step in the country's overall satellite communications programme; it will lay the foundation for building operational communication satellites in the country. Similarly, the applications and experiments to be carried out with APPLE are intended to provide vital inputs for the utilisation of our future operational satellites.

With the Indian National Satellite (INSAT)-IA to be launched next year, the country is making a firm commitment to satellite communications. This decision is based to a great extent on the experience gained during the Satellite Instructional Television Experiment (SITE) in 1975-76 and the Satellite Telecommunications Experiments Project (STEP) during 1977-79.

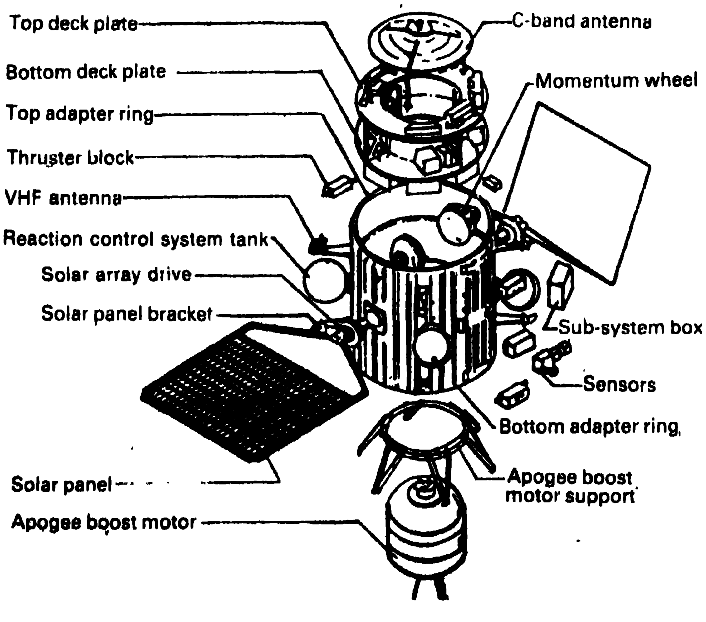
SITE used a US satellite for broadcasting programmes *directly* to specially augmented community TV receivers in over 2,300 villages in India. The responsibility for all the ground hardware, the TV programmes and evaluation was with India. Among the various applications demonstrated during SITE were: programmes for school children, teacher-training (about 45,000 primary school teachers were trained using a multi-media approach), training for agriculturists, and instructional programmes in various fields. "Live" broadcasts were also made.

STEP used the Franco-German Symphonie satellite for two years from 1977 to 1979. A large number of telecommunications experiments were carried out, including the deployment of small, transportable earth stations for use in remote areas or during natural calamities. While one of the transportable terminals was mounted on a jeep (or could be air-lifted), the other was truck-mounted. The latter could transmit TV programmes to the satellite, and was stationed in Lahore for live broadcast to India (via Symphonie) of the Indo-Pak cricket Test matches. Video teleconferencing and tele-medicine experiments were also conducted. For the first time, digital communication techniques were tried out via satellite.

Having thus proven both the utility and capabilities in satellite broadcasting and telecommunications, the country is now ready to go into regular *operational* stage through the INSAT satellites. However, INSAT—I satellites are being bought from abroad and it is necessary to develop our capabilities in the design and development of space hardware for communications just as we have done for ground hardware. The APPLE satellite will be an important step in this direction.

The basic objective of APPLE is, therefore, necessarily technological. It has been defined as: "building and getting launched an experimental body-stabilised geo-stationary communication satellite with its own apogee propulsion, attitude and orbit control systems; and obtaining

Fig: 1. APPLE satellite



SLV-3 flight

THE first developmental flight of India's SLV-3 rocket, fired from the Sriharikota range on 31 May, failed to put the Rohini-II satellite (RS-II) into the right orbit and the satellite, designed to orbit the Earth for 300 days, re-entered the Earth's atmosphere and burnt up after only nine days.

The third and fourth stages of the rocket performed poorly, according to ISRO. Consequently, the satellite was injected into a low orbit—perigee of 185 km and apogee of 425 km against the planned 296 km and 834 km, respectively. ISRO predicted, after the launch, that because of the lower orbit, the satellite would last 90 days but later, on 6 June, it said the satellite might last only 15 to 30 days. Meanwhile, the satellite altitude was dropping by a few kilometres every day, till it eventually re-entered the earth's atmosphere and burnt up due to the frictional heating after orbiting for only 9 days.

Earlier, the SLV-3 (E-01), the first experimental flight on 10 August, 1979 had failed and the rocket had fallen into the Bay of Bengal soon after the launch because of snags in its second stage booster motor. The second experimental flight in July 1980 was, however, a success.

Such setbacks in rocket flights are not rare, though. For instance, the ESA's Ariane launcher, being developed as a competitor to the US space shuttle, had serious problems. The second Ariane test launch from Kourou in May 1980 had ended up in the sea soon after launch because of instabilities in the injection system which damaged the engine. And the launching of Ariane-3, which put the APPLE into orbit last month, was put off twice earlier because of technical snags. Originally, it was to be launched in February this year, but was postponed to March or April and subsequently to 19 June. Ariane launchers use liquid fuels and such problems are well known in liquid-fuelled rocket motors. SLV-3, on the other hand, uses solid fuels.

experience in orbit-raising and in-orbit management."

Despite this technological bias, APPLE's capabilities for applications experiments will be fully exploited. APPLE will focus on a great deal of digital communication experimentation. The experience gained from the limited digital experiments during STEP will be substantially enlarged and enriched. More advanced techniques aimed at further optimising the use of spacecraft bandwidth/power and at reducing the size of ground terminals will be tried out. To this extent, the experiments are more advanced than what is immediately envisaged for INSAT. Thus, the experience and success of the experiments with APPLE will enable their later adoption in the INSAT system.

APPLE is a geostationary communication satellite (a satellite whose orbiting speed is synchronous with the earth's rotation so that the satellite remains fixed over a given place on the earth at approximately 35,900 km altitude). Not only was the satellite designed and developed in India, but the vitally important apogee boost motor (which takes the spacecraft from an elliptical transfer orbit to a circular synchronous orbit) is also Indian. Some characteristics of the spacecraft are given above.

The communications ministry will, of course, be an active partner of ISRO in the utilisation of APPLE. A formal memorandum of understanding has been signed for the experiments (see box on p. 65) to be carried out jointly by ISRO and P&T In addition, to create wider participation, a large number of potential user institutions and agencies, such as the Central Electronics Engineering Research Institute, Pilani, the Tata Institute of Fundamental Research, Bombay, IITs and engineering colleges were offered opportunities for experiments using APPLE. A "non-technical" offer to try out various applications was also made to possible users and other organisations like the Railways and banks.

A major thrust of the APPLE experiments is in the area of digital communication (most of the existing telecommunications network is analogue). Digital techniques provide a number of advantages compared to analogue. Generally, they ensure optimal utilisation of bandwidth and power on the spacecraft, while providing flexibility and versatility. They can handle voice, data or TV picture signals with equal ease; they have greater immunity to noise and offer possibility of signal processing, bandwidth compressions, error corrections, etc. Among the experiments planned with APPLE are TV transmissions with multiple audio channels

Apple characteristics

Three-axis body-stabilised geostationary experimental communication satellite.

Weight at launch: 630 kg.

1200 mm diameter and 1200 mm high cylindrical shell; 4665 mm across deployed solar panels and 1985 mm overall height.

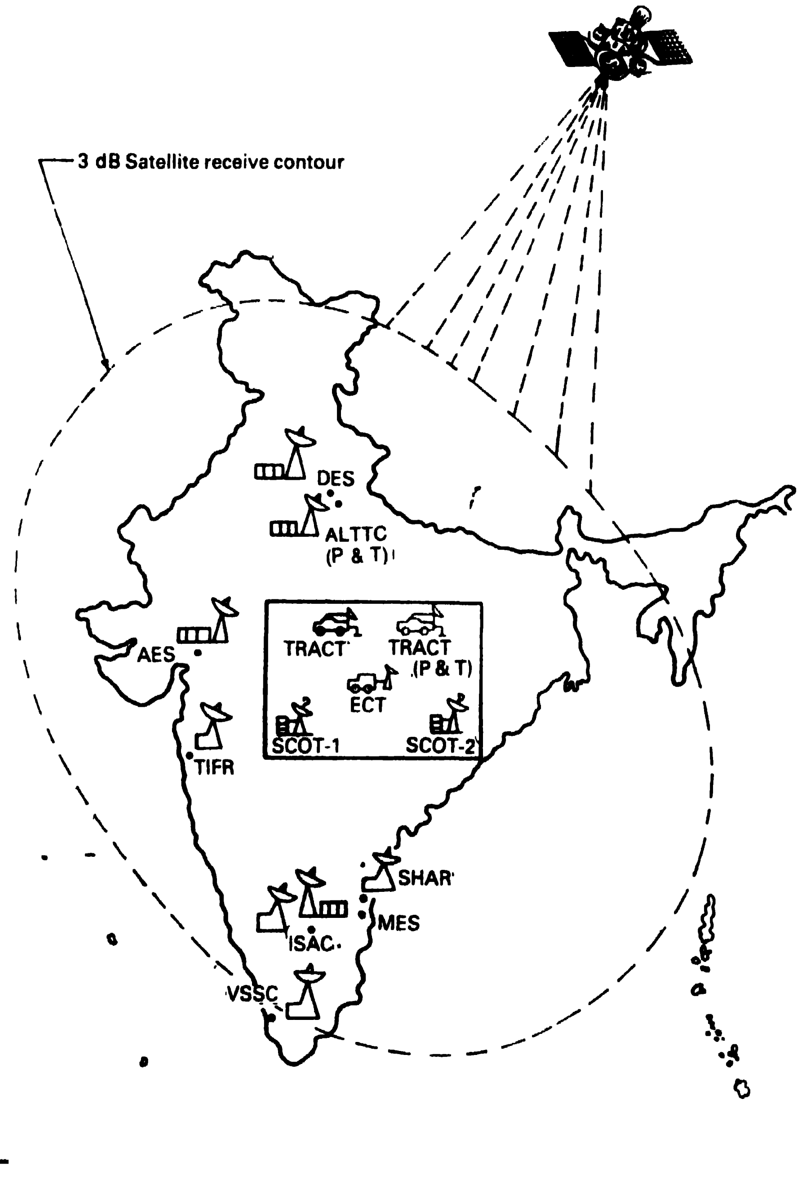
Indigenously developed apogee boost motor for insertion into synchronous orbit.

Driven deployable solar panels with 280 Watts power at beginning of life.

One communication transponder with redundancy operating in 6 and 4 GHz band, 900 mm diameter parabolic antenna.

31.5 dBW peak effective isotropic radiative power (EIRP).

Fig: 2. APPLE utilisation network. The broken circle indicates the area covered within half of the maximum power available from the satellite. The box in the middle shows two truck-mounted transportable terminal (TRACT), two small communication terminals (SCOT) and jeep-mounted emergency communication terminal (ECT). The effort is to configure a small communication terminal in such a way that it could be easily transported and set up in the shortest time. (DES = Delhi air station, AES = Ahmedabad air station, MES – Madras air station.) The network to be used for carrying out the experiments proposed will consist of four major stations—Ahmedabad, Delhi, Madras and the Advanced Level Telecommunications Training Centre (ALTTC) of the Posts & Telegraphs at Ghaziabad. Besides these, small terminals having 6-metre antennae will be available at the Tata Institute of Fundamental Research (TIFR), Bombay, Sriharikota range (SHAR), Andhra Pradesh, the ISRO Satellite Centre (ISAC), Bangalore, and the Vikram Sarabhai Space Centre (VSSC), Trivandrum. The mobile terminals shown in the box will be shifted to different locations depending on the experiment. ISRO and P & T are responsible for setting up the network and the end-links for telephones/TV.



Experiments to be conducted by ISRO and P & T under APPLE utilisation project

Experiments	Major objectives	Significance
1. Time division multiple access (TDMA)	To acquire competence in TDMA technology through design, development and establishment of operational TDMA system compatible with the ground network.	Access to satellite in pre-alloted time slot for each user, permitting utilisation of full power and bandwidth by each accessing station resulting in increased channel capacity. Flexibility of demand assignment over a number of satellite links. Inherits all advantages of digital communication.
2. Spread spectrum multiple access (SSMA)	To develop the technology for SSMA, providing telephone and telegraph links and to demonstrate its suitability for use with small terminals and other applications.	Signal transmitted after adding pseudo noise and spreading the bandwidth. Recovery of signal embedded in noise, and secrecy and security of communication.
3. Random access packet switching (RAPS-COMNEX)	To develop hardware and software for establishing a network consisting of computers and user terminals under random access packet switched mode using a single SCPC (single channel per carrier) channel.	To cater to new type of data communication needs with shared channel Useful for computer sharing, reservation and such applications.
4. TV with multiple audio (TVMA)	To develop hardware for time domain multiplexing (TDM) of audio channels with a video signal using pulse code modulation (PCM) as well as pulse amplitude modulation (PAM) to provide commentary/programme quality audio channels	For TV transmission with multiple voice/music Useful for multilingual country like India.
5. Facsimile transmission	To perform system test of facsimile hardware	For transmitting pictures, texts and hand-written matters.
6. Digital echo canceller	To perform system test of echo cancellers for double talk	To remove annoying effect of echo caused by large time delay in satellite communication.
7. Digital speech interpolation (DSI)	To develop DSI technology for increased capacity with 2M bit PCM (30 channel) scheme	Makes use of pauses during a telephone conversation to increase channel capacity to an advantage of 1:2.
8. Network integration	Development and trial of equipment for trunk automatic exchange (TAX) modification to facilitate transit exchange working.	Facilitates direct dialling to subscriber trunk dialling (STD) destinations connected to the exchange via satellite circuit.
9. Digital communication multiple access (DCMA)	To try digital satellite link for telephony using PCM/QPSK (four-phase phase shift keying) link in frequency division multiple access mode	To provide good quality link offering inherent advantages of digital communication. Permits use of DSI to double the channel capacity.
10. Small communication terminal (SCOT)	To design and develop an easily portable small communication terminal which can be deployed and used in a short time and provide voice/teleprinter link.	To provide emergency voice/teleprinter links for various requirements.

(obviously of special relevance to us, being a multi-lingual country), computer-interconnection, use of small, highly portable terminals for reception, time-division multiple access experiment, spread spectrum communication, etc (see table above).

Besides these technological experiments, efforts are continuing to conceive and define experiments with socio-economic goals. Thus, an experiment in "tele-teaching" has been finalised. This will involve IITs, ISRO and P&T in a course on satellite communications to be given via the satellite. APPLE will be used to transmit a prepared TV programme on each of the chosen topics. This will be received at various locations and the participants at these locations can then ask questions (relayed via APPLE) to the presenter/lecturer, who will be at the programme originating centre and will reply to them (again via APPLE). Another experiment, involving the tracking of wagons, is being discussed with the Railways. The objective is to see if the use of a satellite link can help to keep better track of wagon movements and thereby increase efficiency of wagon utilisation.

Discussions are also going on about a possible experiment in the field of banking transactions, where time is important. The utilisation of APPLE for news agency messages and for facsimile transmission of newspapers is being discussed.

The APPLE ground network (Fig. 2) is necessarily limited. Even so, there is a real challenge to the users to come up with imaginative and relevant experiments.

Mr. Pramod Kumar is Project Director, APPLE Utilisation Project (ISRO). He is also Head of the Digital Communications Division in the Communications Area of the Space Applications Centre, Ahmedabad.

Mr. Karnik is Co-chairman of the Planning and Projects Group at the Space Applications Centre, Ahmedabad.

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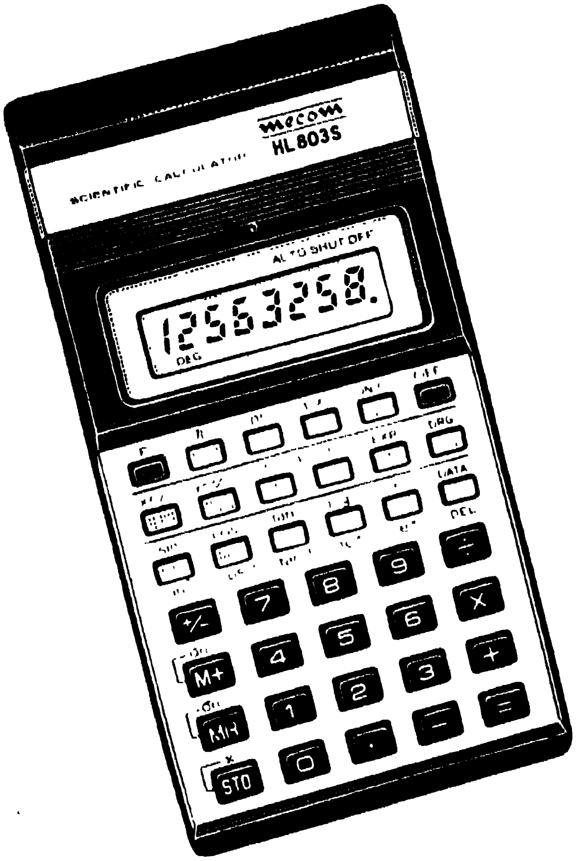

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IC photo-electric remote control

IF YOU are too lazy to get up from your sofa to switch on or off your TV, radio, tape-recorder, record player or any other electrically operated equipment, you can take the help of this device actuated with an ordinary torch-light. One flash on the device will turn it on and it will remain "on" till another flash turns it off. Thus, by remote control you can turn on or off anything which works on electricity without getting up or doing it yourself.

The device explained below is an improved version of the IC Remote Control for your TV or Radio (SCIENCE TODAY, March 1979, pp. 61-62). Use of two integrated circuits, IC 555 as a monostable multivibrator and IC 4027 as a flip-flop, that is, bistable multivibrator, makes the unit respond very fast to the light signal. The use of IC-4027, C-MOS dual J-K master slave flip-flop eliminates the need for additional relay contacts in the electronic circuit.

The device basically consists of four stages: photo-electronic trigger circuit using the LDR, IC 555 used as a monostable multivibrator; C-MOS IC-4027 used as flip-flop, that is, bistable multivibrator; Darlington pair amplifier for operating relay; and the necessary DC power supply for all these circuit stages.

In the standby state, that is, when no trigger pulse is applied to trigger terminal No. 2 of IC 555, the control flip-flop provides high output, which holds the discharging transistor in conducting state which clamps the charging capacitor 'C' to the ground level. The flip-flop also drives the inverting amplifier to provide low output. The internal voltage divider, consisting of three 5 K ohm resistors in series, provides 2/3rd Vcc and 1/3rd Vcc to the upper and lower comparators, respectively. These two voltage levels thus determine threshold and trigger levels of the two comparators.

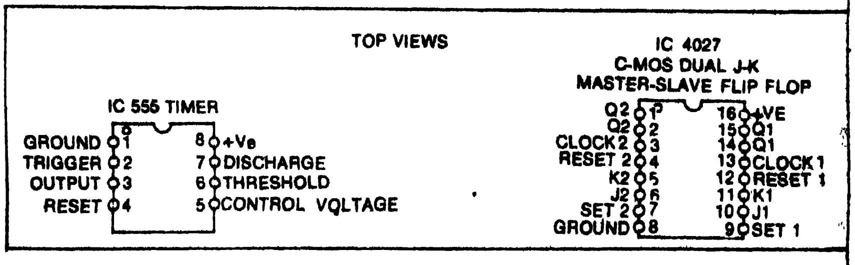
When the light falls on the LDR, the momentary voltage drop across it, because of increased conduction, provides the necessary negative impulse to the trigger terminal of the IC 555. This causes the lower comparator to provide the output which changes the state of the control flip-flop from high to low. The control flip-flop thus cannot hold the discharging transistor, and the inverting output stage provides high output at terminal No. 3 of the IC. As the timing capacitor 'C' is now unclamped, it starts charging through the 100 K resistor. When the capacitor charges to 2/3rd Vcc, which is the threshold level of the upper comparator, it resets the flip-flop back to its normal high state. The flip-flop thus simultaneously discharges the timing capacitor 'C' through the 330 ohms current limiting resistor and the discharging transistor O14, bringing the output again to the low level. This completes one cycle of monostable operation.

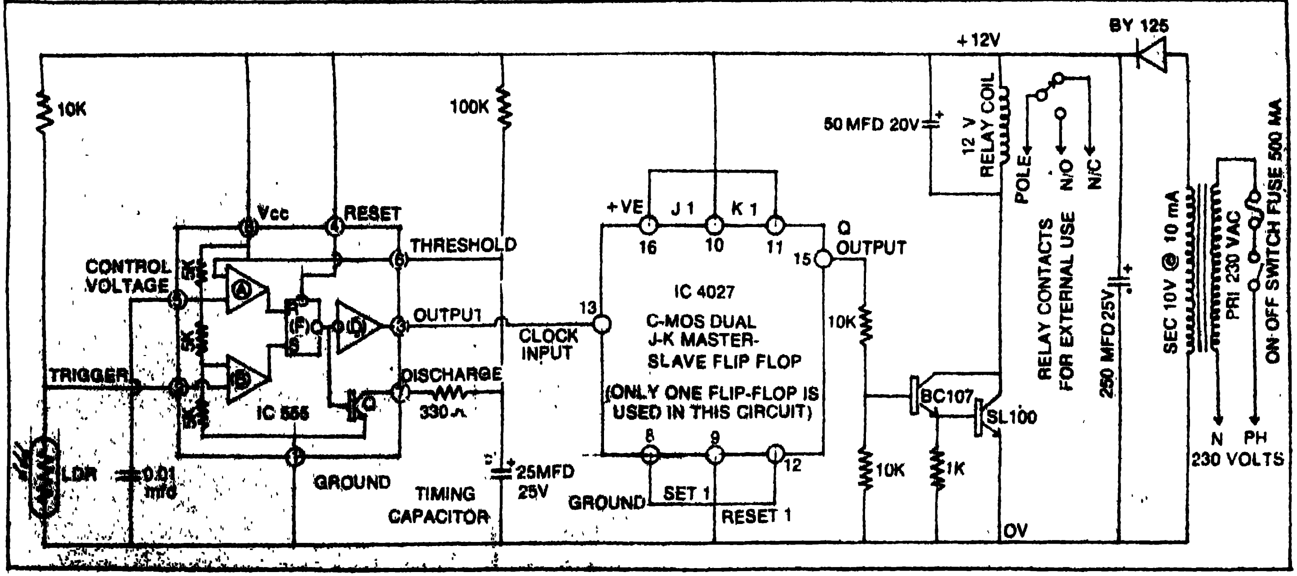
The output provided by IC 555 at its terminal No. 3 is fed to the clock input terminal of the C-MOS dual master slave flip-flop IC 4027. The IC 555 monostable multivibrator goes through one monostable operation, the clock input to IC 4027 drives its output from low to high. The state of output provided by IC 4027 remains high till IC 555 goes through one more monostable operation. The output of IC 4027 is used to drive the Darlington pair, which in turn drives the 12V relay coil.

Thus, when the light falls on the LDR, the relays changes state and remains in the changed condition till the light falls once again on the LDR. The relay contact can be used to operate the electrical appliance.

The monostable multivibrator stage using IC 555 provides a monostable period of four to five seconds. This period is to avoid continuous "on-off" operation of the relay. Without this period the circuit would be unable to select a suitable stable state. This phenomenon is called 'hunting'. If the LDR remains continuously illuminated, then the relay will go into hunting action.

The LDR has to be mounted inside a tube of diameter about 15 mm and length about 100 mm. The inside of the tube should be painted with black mat paint. The tube containing the LDR should be placed pointing towards you such that no extraneous light will interfere with the LDR and when you require to operate the device you can illuminate the LDR briefly with the torch-light





You will need:

Semiconductors. IC 555—1 No.; IC 4027—1No

Transistors BC 107—1 No., SL100—1 No.
Diode: BY 125 or BY 126—1 No.
LDR: —1 No.

Capacitors: Electrolytic—250 mfd, 25V—1 No.; 50 mfd, 25V—1 No.; 25 mfd, 25V—1 No. Ceramic or polyester—0.01 mfd—1 No.

Resistors (all ½ watt type: 100K—1 No.; 10K—3 Nos.; 1K—1 No:; 330 ohms—1 No.

Relay : Coil voltage 12V DC with resistance more than 250 ohms with two sets of changeover contacts suitable for operating the electrical equipment.

Transformer (made to order) Pri: 230V AC. Sec: 10V at 100 mA —1 No.

Approximate cost of the above electronic components in the Bombay market, Rs.125.

Misc On/off switch, fuse 500mA with holder, solder, IC experimenter's veroboard, suitable enclosure, connector strip, wires, screws, mains plug, etc

ANIL V. BORKAR

BRAIN TEASERS

Prince Charming

THE newcomer told the old girls shyly that a boy, wearing a blue T-shirt and faded jeans, had stopped his scooter and given her a bunch of roses. She further added that the boy was fair, quite tall and had a very becoming beard. The old girls set out guessing. Only six boys came on scooters—Anand, Bipin, Chetan, Dick, Edward and Farid. So, who could it be?

This is how the discussion proceeded:

First girl: Anand, Edward and Farid are very fair.

Second girl: Why, Chetan and Dick are fair, too! Of course, I could not say the same about Bipin.

Third: A beard looks best on Farid, I wish he were taller.

First girl: It suits Anand, Bipin, Edward and Chetan also.

Second girl: How Edward hates anything faded!

Third girl: I know. But don't faded jeans look fantastic with blue T-shirts! I wish Anand would buy a blue T-shirt to go with his faded jeans.

Now, can you tell who he was?

SUDHA JOHRI

(Solution next month)

Solution to last month's Brain Teaser

Add a Square

Let the square to be added be a^2 and let the sum be b^2, so that

$1691 + a^2 = b^2$

$b^2 - a^2 = 1691$

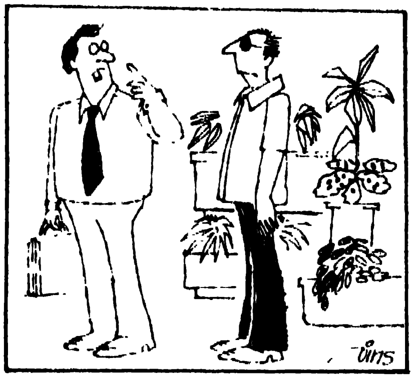
$(b + a)(b - a) = 89 \times 19$

$b + a = 89$

$b - a = 19$

Solving, $b = 54$ and $a = 35$.

So, the squares are 1225 and 2916.



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AWARDS AND APPOINTMENTS

Dr. S. Ramaseshan to head IISc

DR. S. Ramaseshan, currently joint director of the Indian Institute of Science, Bangalore, is to be its next director with effect from 31 July. Earlier, he was head of the Materials Division, which he founded, of the National Aeronautical Laboratory, Bangalore. He has contributed significantly to teaching and research in composites science, crystallography and high-pressure physics. He was awarded the S.S. Bhatnagar Award in 1968 and the Jawaharlal Nehru Fellowship in 1977.

Dr. Nayudamma is JNU's VC

DR Y. Nayudamma, a distinguished scientist and former Director-General of the Council of Scientific and Industrial Research, has been appointed vice-chancellor of Jawaharlal Nehru University for a period of five years.

International Award for Teaching Aid

MR U. Varadaraya Nayak, a physics teacher in the Casia High School, Mangalore, has won the American Association of Physics Teachers' International Science Award for his invention, which demonstrates the concepts and principles of the working of the AC and DC dynamos. He is the first Indian to win the award since the competition commenced in 1957. The apparatus has already won the top award in the all-India physics teaching aids contest held at Nagpur in 1980.

Prof. C. N. R. Rao elected to Yugoslav Academy

PROF. C. N. R. Rao, Chairman, Solid State and Structural Chemistry Unit and Materials Research Laboratory, Indian Institute of Science, Bangalore, has been elected a Foreign Member of the Academy of Sciences Yugoslavia.

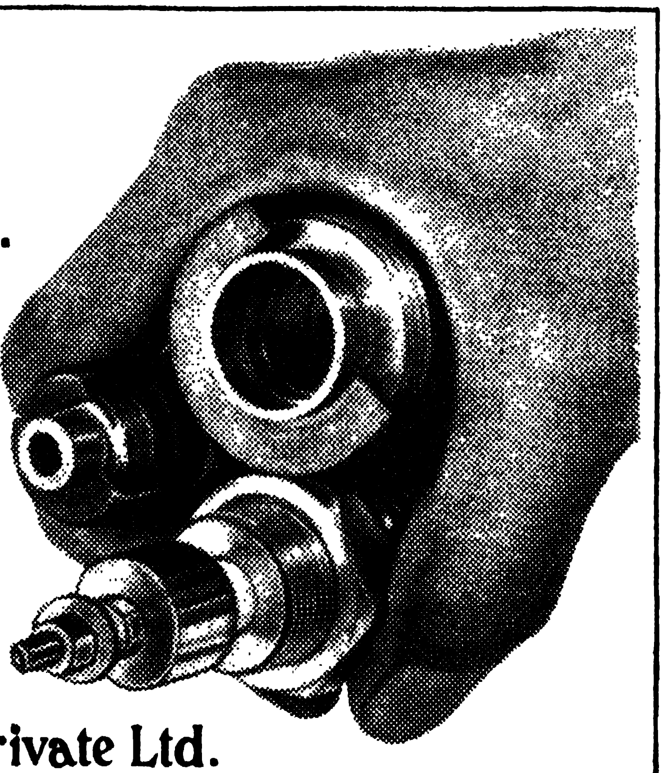
Senior Coal Scientist Award

DR. P. N. Mukherjee, Deputy Director, Central Fuel Research Institute, and Dr. D. Chandra, Professor, Department of Applied Geology, Indian School of Mines, Dhanbad, have been named jointly by a National Committee for the Senior Coal Scientist Award for 1980, instituted by the Ministry of Energy two years ago. The Award is given for meritorious research in coal science and technology.

Dr. Mukherjee has made significant findings on the importance of moisture, which is held in coal by chemical forces and found that the active sites responsible for retention of moisture are the functional groups such as hydroxyl and carboxyl. Dr. Chandra has developed a technique by which the quality of coal lying at a greater depth could be predicted from the outcrop sample, this has helped the coal industry world-wide to save drilling expenses during the early prospecting of coal.

Pitambar Pant National Environment Fellowship

Dr. Kothandaraman Krishnamurthy, Professor of Marine Biology, Centre of Advanced Study in Marine Biology, Annamalai University, has been awarded this year's Pitambar Pant National Environment Fellowship. The award, instituted by the Department of Environment, is tenable for two years, and carries an amount of Rs 2,500 a month, in addition to research and contingent grants.



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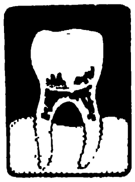
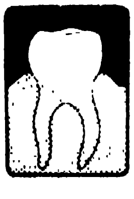
Gum troubles could mean loss of healthy teeth



Dentists say that if teeth are not cleaned properly a thin layer of bacteria called plaque, which forms around your teeth and gums, starts accumulating. This leads to tartar which weakens and pushes away gums causing even healthy teeth to fall out. Gum troubles can also harm health in general.

Forhan's protection for the gums



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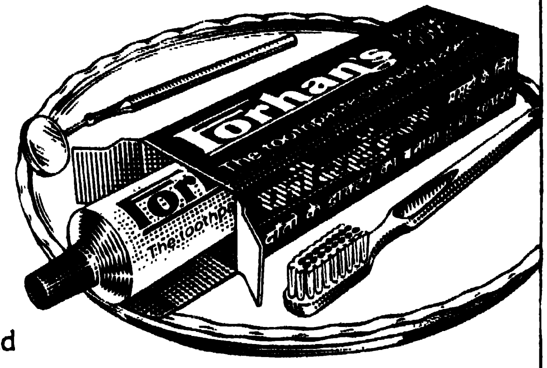

Forhan's For the gums

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MEETINGS CALENDAR

September

Research trends in animal morphology, physiology and ecology with special reference to Hilly region, Srinagar, Garhwal, UP, India (Prof. H.R.Singh, Head, Dept of Zoology, University of Garhwal, Srinagar, Garhwal-246 174, U.P.). (Dates not intimated.)

6-13: Photochemistry, X int. conf., Crete, Greece (Dr. P. Rentzepis, Bell Laboratories, Murray Hills, New Jersey, USA).

7-12: Solid state nuclear track detectors, 11th int. Conf., Bristol, UK (P.H. Fowler, H.H. Wills Phys. Lab., Tyndall Ave. Bristol BSB ITL UK).

13-17: Three decades of nuclear power, int. conf., Vienna, Austria (IAEA, Austria).

14-17: Threatened plants of India, Seminar, Dehra Dun, India (Dr. S.K. Jain, Director, Botanical Survey of India, PO Botanic Garden, Howrah—711103, West Bengal, India).

15-19: Medicinal plants and spices, Fourth session of the Asian symp., Bangkok, Thailand (UNESCO).

15-20: Oceans, mankind and ethics, int. seminar, Lisbon, Portugal (UNESCO).

16-19: Earth resources for Goa's development seminar, Panaji, Goa (Mr. A. R. Gokul, convener and executive secretary, seminar on Earth resources for Goa's development, Geological Survey of India, 78, Diagonal Road, III Block, Jayanagar, Bangalore - 560 011)

20-23: From genetic experimentation to biotechnology: the critical transition, symp., Rome Italy (Dr. V. Sgaramella, Instituto di genetics Biochemica ed Evoluzionistica del CNR, Via S Epifanio, 14-27100 Pavia, Italy).

22-24: Seed proteins, int. symp., Versailles, France, (Dr P.J. Lea, Department of Biochemistry, Rothamsted Experimental Station, Harpenden, Herts. (UK) AL5 2JQ).

28-2 October: Industrial applications of radioisotopes and radiation technology, int. conf., Grenoble, France (IAEA, Vienna, Austria).

October

Plant breeders, national congress (Mahabal Ram, Indian Agricultural Research Institute, Regional station, Karnal-132 001) (Dates and venue not intimated.).

(5 days): Cytology and genetics, 4th all India congress, Hyderabad, India (Prof. G.K.Manna, convener, 4th All India congress of cytology and genetics, Department of zoology, Kalyani University, Kalyani-741 235.). (Dates not intimated)

5-7: National Academy of Science, India, the 51st annual session, Cochin University, Cochin (H. C. Khare, the National Academy of Science, India, 5 Lajpat Rai Road, Allahabad-211 002.).

4-13: Radio and TV, int. exhibition, Berlin, (AMK Berlin, erlin, Postfach 191740, Messedemm, 22, D-100 Berlin 19W. Germany).

5-18: Cloning of plant genes, course, Arhus University, Denmark (Prof. D. Von Wettetein, Carlsberg Laboratory, Gamle, Carlsberg Vej 10, DK-2500, Copenhagen Valby, Denmark).

6-9: Comparative anatomy of DNA replication and its control, and EMBO workshop, Dourdan, France, (S. D. Ehlich, CNRS Univ. of Paris VII, 75221 Paris, France).

19-22: Large body impacts and terrestrial evolution, geological, climatological, and biological implications, meeting, Snowbird, Utah, USA, (Earth impact conference. Lunar and Planetary Institute, 3303 NASA Road 1, Houston, Texas 77058, USA).

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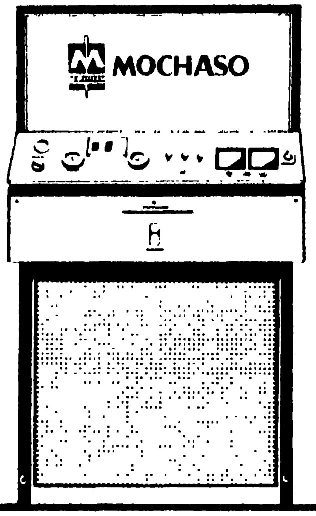

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IF...

... there were no microorganisms

MY SON, bedridden in the hospital with acute gastroenteritis moaned: "Wouldn't it be nice if there were no microbes? Then there would be no infections and no diseases, at least those caused by microbes." But then we would not have antibiotics either—the group of very powerful medicines like penicillin and tetracycline which are generated by microbes like fungi! Well, if there were no disease-causing germs, why would we need antibiotics?

Although antibiotics are the first microbial products that come to the mind, especially when in a sick bed, drugs are not the only things that microbes provide us. Microbes have a lot of other uses in our day-to-day life. If there were no microbes, there would be no *Lactobacillus bulgaricus* which forms curds or yoghurt by fermenting milk sugar lactose to lactic acid. Yoghurt also contains another microbe, *Streptococcus thermophilus*, which adds a characteristic creamy flavour.

Take *Saccharomyces cerevisiae*—an yeast. Without it, we would not be able to bake our daily bread, or cake if one has a sweet tooth. It ferments the sugars in the dough for a brief period and the carbon dioxide produced during fermentation forms tiny bubbles which leaven the bread. The cheese that goes in between the slices of bread to make up the sandwich is also caused by microbial fermentation of milk. Even *idli* and *dosa* or *dhokla* are partially fermented by microbes. *Jalebis* become crisp only if the batter is allowed to ferment.

If there were no microbes, we would be in low spirits, for without fermentation there would be no wines and beers. Almost each exclusive wine acquires its special flavour and taste from the growth of an almost unique species of wild yeast.

But man doesn't live—or grow—by bread and wine alone. He needs other crucial nutrients, like the vitamins. Here again, microbes help out. Vitamin C or ascorbic acid is made from a plant product, sorbitol, by a series of chemical transformations; in one of these steps, the material is exposed to a bacterium *Acetobacter suboxydans*, which oxidises it more gently than a chemical reaction does. Vitamin B_2 or riboflavin is produced microbiologically using a variety of yeasts.

Yet, this contribution of microbes to our food and nutrition pales when one thinks of the debt we owe to the food-growing, nitrogen-fixing bacteria. One of the major contents of our food, be it vegetarian or non-vegetarian, is protein. And the basic constituent of proteins is nitrogen. The atmosphere consists of some 80 per cent of this gas in the molecular form but the molecule does not easily enter into spontaneous chemical reactions. If it is to go into making the protein molecule, it has to be "fixed". The plants do it partially by picking it from the nitrates in the soil. However, microbes like *Rhizobium*, living symbiotically with the plants, help fix the nitrogen and thus bring about enrichment. Without microbes, no nitrogen could have been converted to nitrates; or once converted, it would have stayed that way exhausting the atmospheric supply of this important gas, if it were not for the denitrifying bacteria.

In fact, microbes can be counted as a major factor in helping the growth of man's civilisation if industries are considered a major component of this civilisation. We have already seen that alcohol, a major raw material of industry, is produced by the process of fermentation carried out by microbes. Another equally important raw material, sulphuric acid, can also be produced by oxidation of sulphur brought about by bacteria like *Thiobacillus thiooxidans*. In fact, there is compelling evidence that bacteria were responsible for the conversion of sulphate to sulphide, ultimately leading to the formation of world's major sulphur reserves. Sulphur, however, is not the only mineral deposited by microbes. Coal, sodium, iron, molybdenum, titanium, chromium, zinc and that genie of the atomic age, uranium, can all be leached out from the pyritic strata by microbes.

Industry also needs power which in turn needs fuel. Methane, which is one of the main components of natural gas, is formed by methane bacteria. There are even speculations that oil formation has been aided by microbial action. And now, it appears, that bacteria of the type, *Methylosinus trichosporium*, which possess a highly specific and effective oxygenase enzyme could be coaxed into forming a biofuel cell producing electricity directly from fuel without any energy wasting intermediate steps.

Scanning electron micrograph of *B.thuringiensis*(top) and the red hairy caterpillar *Amsacta moorei*, its victim, above

Even the most ordinary microbes do us great service. Take, for example, *Escherichia coli* which lives happily in our intestines and helps in digestion by providing certain enzymes. In the process, they sacrifice their lives. This bacterium has been the workhorse of modern biologists. For, if there were no germs *(E. coli)*, we might not have been able to break the genetic code so easily, revealing the mechanisms which ensure that hereditary traits pass on from generation to generation. Lack of this knowledge would have stunted, even aborted, the development of genetic engineering which persuades industrious and innocuous microbes to mass produce several vital substances like insulin, interferon or somatostatin. Nor would it have been possible to develop the technology that led to the birth of the test-tube baby.

Obviously, microbes have been unjustly branded as mere disease-bearing agents. For every one pathogenic strain, there are several benign and helpful strains of microbes. Some of them are indeed infectious. And if microbes like the small pox virus, or *Vibrio cholera* or *Salmonella typhosa*, *Clostridium tetanii* which still incapacitate millions of people, and at times cause fatal illness weren't there, it could no doubt be a better world. But then there are others like *Bacillus thuringensis* which control pests like caterpillar that destroys foodstuff or mosquitoes that are responsible for the spread of malaria.

Microbes were the first to arrive and exist on the Earth, millenia before man did. It is they who converted the Earth's forbidding environment into one that is conducive to life and paved the way for the evolution and sustenance of *Homo sapiens*. According to the controversial British astronomer Fred Hoyle, we owe our lives to those distant microbes who paved the evolutionary pathway. And it is the exciting discovery of the microbe *Azatobacter bijerincky* which promises one day to help man tame the hostile atmosphere of Mars in order to colonise it.

G. P. PHONDKE

Dr. Phondke is Head, Radiobiology and Occupational Health Section, Medical Division, Bhabha Atomic Research Centre, Bombay

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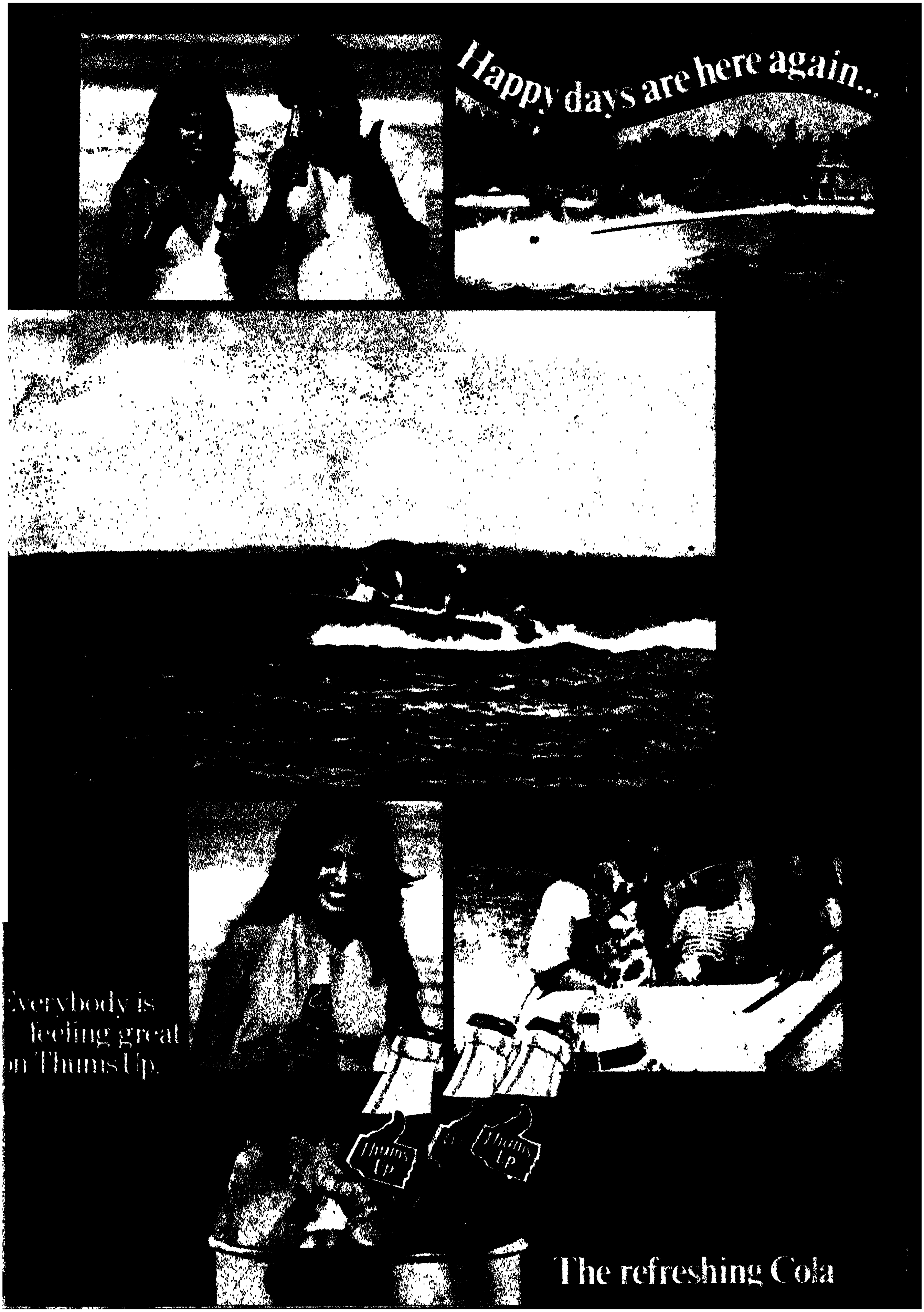
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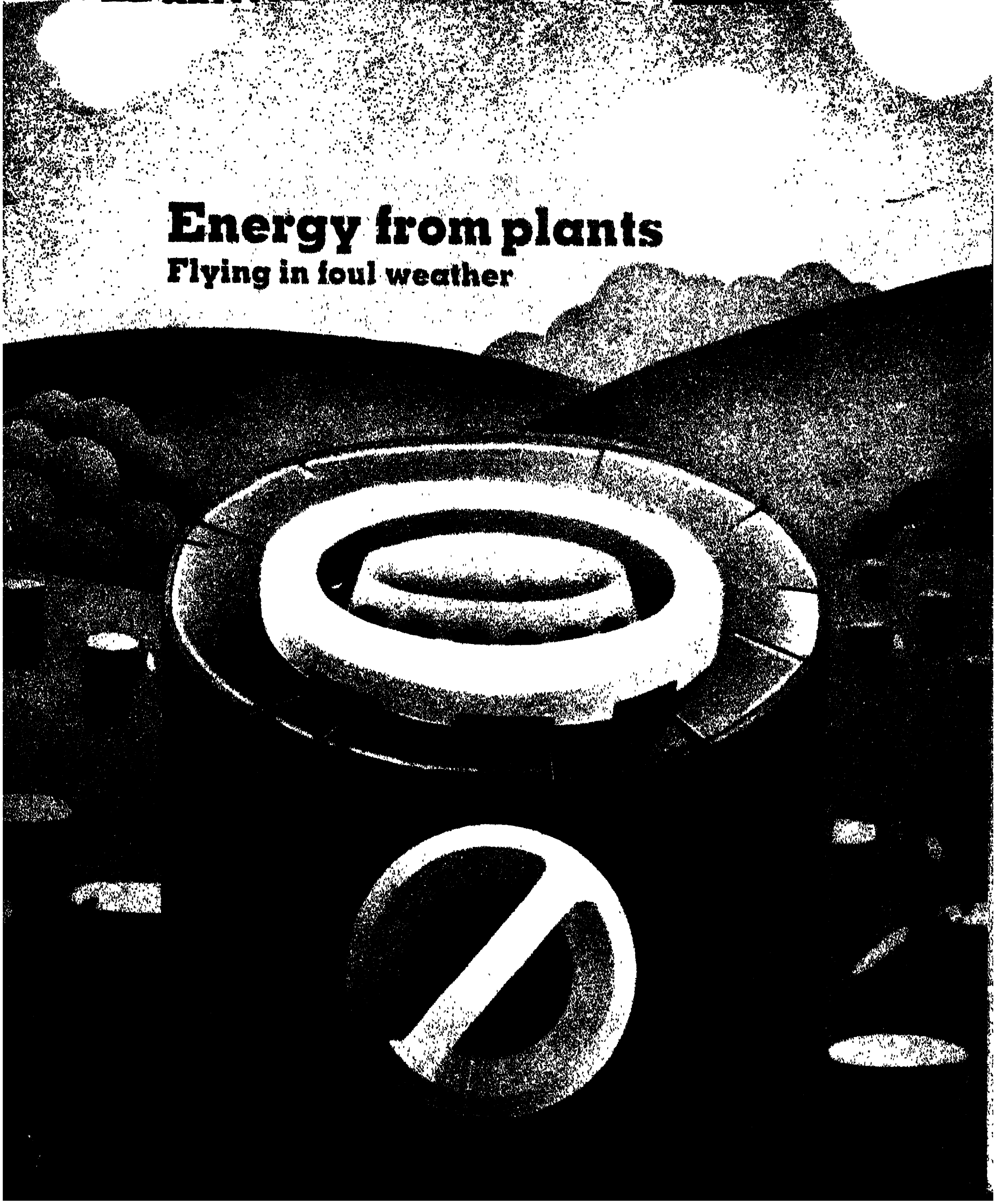

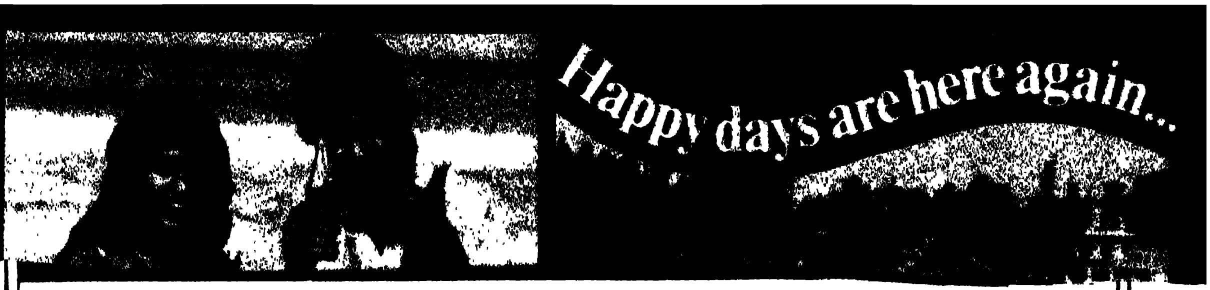
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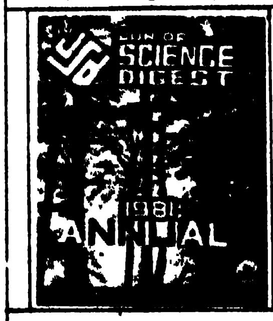	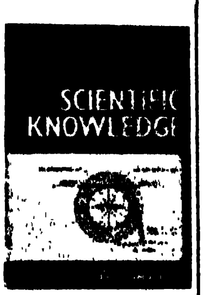	(ADD Rs. 3.50 for Regd. Postage)	

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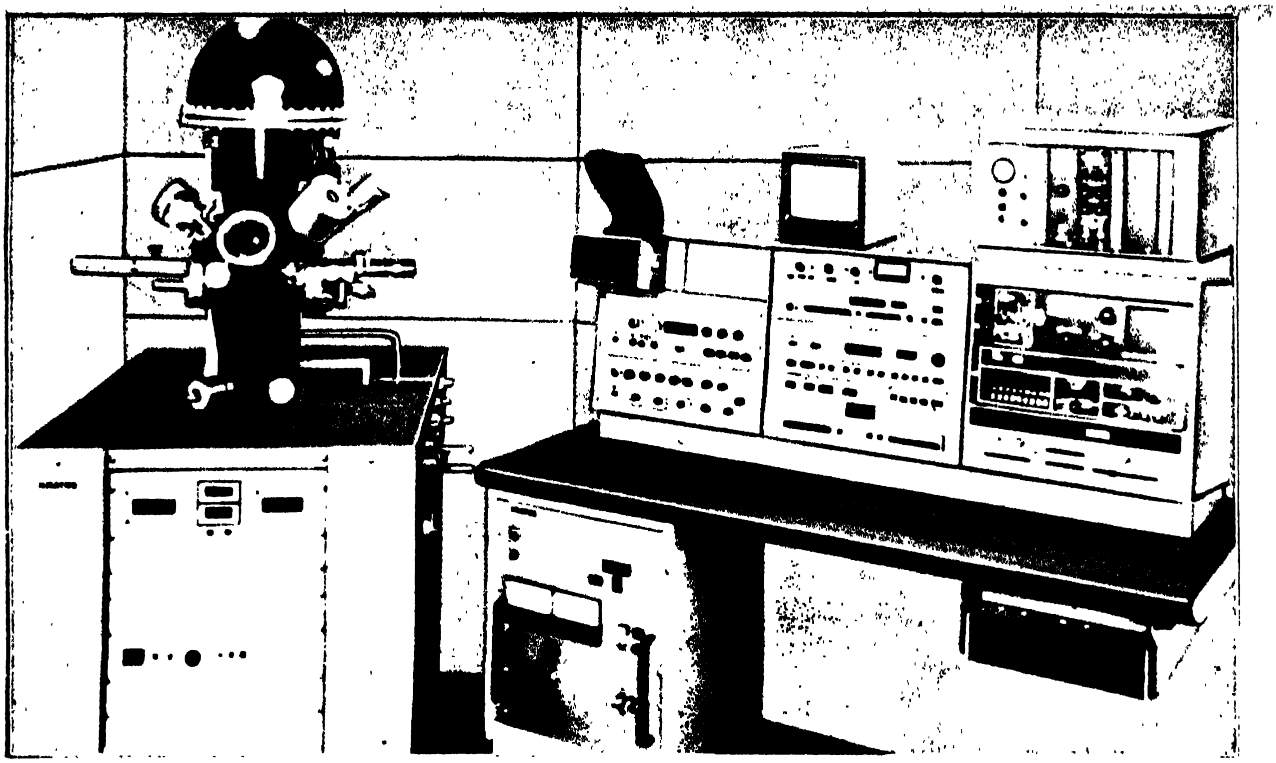

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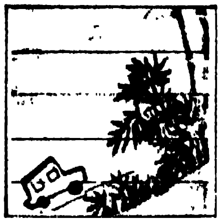

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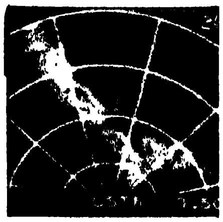

Flying high in foul weather

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Besides causing accidents, bad weather can disturb air traffic and cost millions of rupees in extra expenses

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LETTERS

SUPPLEMENTING VEGETARIAN DIETS

ONE important thing that K.T. Achaya ("Are Vegetarians Ill Nourished?" March 1980) has not stated clearly is that the lack of methionine in vegetarian diets can be made up from the proteins of cereals or potatoes. It should be mentioned that *dal* contains only a small amount of methionine. Moreover, non-haem iron absorption from the gut is also hampered by phosphates along with phytates

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THE NATURE OF HOMOEO DRUGS

BOTH P.M. Bhargava and D. Balasubramanian (Letters, May 1981) have enquired about the nature of the active principle in homoeo medicines.

It was G.O. Barnard who, based on NMR studies of 10^6 dilutions, proposed that homoeo medicines consist of "sterospecific isotactic polymers" of the solvent with "self-replicating qualities". According to him, this happens due to the impact of the solute on the OH ions of the solvent (which may be alcohol or water) during potentisation of the drug through succussion. This is said to hold good also for triturations (drugs prepared by grinding in sugar medium).

This explanation has been generally favoured by the workers quoted below. Amongst these, the work by Aditya Kumar and Ruplal Jussal (1981) is especially relevant. They have shown that the surface tension of homoeo medicines increases proportionately as their dilution is increased. Thus there is no question of the pharmocons splitting into subatomic particles in dilutions, as is generally believed. It is the rearranged solvent molecules induced by the drug which act and cure ailments.

Not only Bhargava and Balasubramanian, but other readers too, may be interested in looking up the following references to get some understanding: **1.** Barnard, G.O., "Mixrodose paradox: a new concept", *Journal of the American Institute of Homoeopathy*, **58** 205 (1965); **2.** Smith, R.B. & Boerick, G.W., "Modern Instrumentation for the evaluation of homoeopathic drug structure". *Ibid*, **59** 263 (1966); **3.** Stephenson, J.H., "On the possible field effects of the solvent phase of succussed high dilutions". *Ibid*, **59** 260 (1966) ; and **4.** Aditya Kumar & Ruplal Jussal, "A hypothesis on the nature of homoeopathic potencies". *Hahnemannian Gleanings*, **48** 131 (1981).

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SUB-ELECTRONIC SIZES: SO THAT'S IT

THE views of both Bhargava and Balasubramanian on the sub-electronic sizes of homeopathic dosages confirmed what I had long suspected, but had never got around to working out for myself. Homeopathy is, I believe, a great advance. In homeopathic medication the doses are kept so small that they can never do any harm (provided, of course, that the water is properly distilled).

EDWARD WHEELER

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THE BAD TASTE OF CIGARETTE ADVERTISEMENTS

THE hazards of cigarette smoking are well known. Many newspapers, periodicals, and TV companies in the developed countries have therefore stopped publishing cigarette advertisements. Also, cigarette companies have, under law, to state on cigarette packets and with their advertisements that smoking is harmful to health.

Cigarette advertisements in SCIENCE TODAY are indeed very surprising and distressing to readers. This should in fact be replaced by warnings against smoking in every issue, and such warnings should be made prominent.

J.M. GANGULI

Professor of Physics
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NOT FUNNY?

R.K. LAXMAN's cartoon on the absent Russian scientist (This World of Science! June 1981) is in very bad taste and out of place in a science magazine. Despite being behind the USA in several fields, the USSR has made a lot of progress in many fields and even leads in some of these. Notwithstanding western propaganda, the technological progress of the USSR indicates that it has a large body of happy well-equipped scientists and similarly satisfied people to back them up.

People in India should stop talking about the supremacy of the USA over the USSR or vice versa and, instead, consider how much better off both those countries are when compared to India.

S.SASTRY

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JIPMER
Pondicherry 605 006

WHERE CREDIT IS DUE

IN "More Nitrogen for More Food" (April 1981) a map (Fig. 4) depicts the nitrogen fertility status of Indian soils. While no reference to this map is made in the text, the source from where it has been taken has also not been acknowledged. It was first published by us in *Fertiliser News*, November 1980.

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R.HASAN

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New Delhi 110 012

CORRECTION

Prof. M. K. V. Bappu is Director of the Indian Institute of Astrophysics, Bangalore, and not of the Indian Institute of Science as printed on p. 30, SCIENCE TODAY, June 1981. The error is regretted.

VIEWPOINTS

The Information Revolution: its implications for India

LIVING in the last quarter of the twentieth century, we are on the threshold of a new age: The Age of Information. Information has suddenly become central to much of human activity, and the key to economic development. With its inseparable twin, communication, information constitutes the nervous system of modern society.

We often hear of the term "information explosion", used to describe the abundance of information and the bewildering range and variety of the tools that have become available for dealing with it. Yet, they do not by themselves constitute the information revolution. Even the ever-increasing realisation that information is a vital resource and worthy of vigorous pursuit in order to gain power and control over men and matters is only a necessary condition but one not good enough for the onset of an information revolution. What use is all that information, if you cannot lay your hands on the particular piece of information which is most relevant to your purpose when you need it? It is the possibility of instant access to sources of knowledge which makes us wonder if the impact of the information revolution is going to be even more far reaching, or more consequential, than that of the industrial revolution.

The abundant availability of information is nothing new. It was an inevitable consequence of the invention of printing. But instant accessibility to almost any portion of the recorded store of human knowledge became possible only now, thanks to the happy confluence of computers and telecommunications—advances in both of which owe a great deal to the development in modern electronics.

"Compunications"

We can conveniently trace the roots of this revolution to the publication by William Shockley in 1952 of the theory of the field effect, transistor, which led in quick succession to a series of other significant developments culminating in the mighty microprocessor which forms the heart of the microcomputer and which can be used in any situation which historically utilised some form of information processing technology, be it electronic, mechanical, pneumatic or hydraulic.

The phenomenal growth in the power of computers can be grasped from just one example: The capabilities of ENIAC (one of the earliest computers, constructed in 1946 at a cost of several million dollars) can now be reproduced at less than $100 using a microprocessor chip. Such a circuit, occupying only a single printed circuit board, would be 20 times faster than ENIAC at performing calculations. Also, it would be 10,000 times more reliable, require only 1/56,000 times the power and 1/300,000 times the space. An equivalent gain in the automobile industry would make a custom-built luxury coach available at less than 50 paise!

Correspondingly, there have been rapid advances in the communications sector. We have come a long way from the days when telephone calls even within a small town had to be made through an operator to the days of direct dialling between cities thousands of kilometres apart. We have moved from crossbar exchanges to space-division and time-division electronic switching systems. From mere voice and data communication in the early sixties we have come to facsimile and video-transmission. From copper wires we are switching over to glass fibres which can simultaneously carry hundreds of conversations without the slightest overlap. And from microwaves and radiowaves we are moving over to laser beams to carry messages. Integration in electronic circuits and systematisation in computers have been matched by digitisation in communications. What is more important, it is now possible to establish person-person, person-computer and computer-computer interactive networks irrespective of the distances separating the different stations or the number of stations or the number of units involved.

The merger of computer and communications technologies into a common stream, which Anthony Oettinger, chairman of Harvard University's Program on Information Resources Policy, calls the *compunications technologies*, has opened up the possibility of unprecedented control over the entire cycle of information. Computers can be used to store, process and retrieve vast quantities of information including text, tabular data and images, and communication channels can help instant dissemination and delivery of information. Computers have evolved to the point where communication is a major part of their activity, and "the traditional use of computers as calculating engines for numerical work is rapidly being replaced by a new principal role—that of managing, storing, retrieving and distribution of information", says Philip Abelson, editor of the US journal, *Science*.

Thanks to the merging of telephones, computers and television into a single yet differentiated system, it is now possible for anyone, sitting in his drawing room, to have information in real time, that is, to be able to witness far-away events "live" as they occur, be it the launching of a spacecraft, or the Wimbledon finals. Newspapers and magazines, edited and made up at one centre, can be (and many are) printed almost simultaneously at different centres, often separated by continents. In the words of Daniel Bell, we are in an era of "perfect information".

It is not just the speed which matters; more significant is the entirely new way of organising communication. Now research teams, office managers, and government agencies can translate new research findings, and give orders or financial information for further action elsewhere. It is not just mere purveyance of information by new means; the communications infrastructure has gone far beyond, to the provision of better intellectual capital to the decision makers. Consider, as an example, how this revolution has affected and tremendously altered the global economy of scientific and technological information (STI).

Evolution of STI systems

Prior to 1900 and till the early years of this century, tools to facilitate scientists' search of the literature such as abstracting periodicals, were conceived and run by groups of scientists themselves. For example, *Chemical Abstracts* was established by the American Chemical Society, and *Refrativnye Zhurnal* by the Academy of Sciences of Czarist Russia. The manually compiled abstracts appeared regularly as printed books. Subscribers got them by surface mail. The early abstracting services were almost always built around scientific disciplines such as chemistry, physics, electrical engineering, biology and so on—a reflection on the way scientific research was organised at that period.

During the interwar years and in the early fifties, the initiatives for establishing new information systems started coming from quasi-government agencies, such as the national research councils. A fine example is the Conseil National de Recherche Scientifique (CNRS) in Paris which started publishing *Bulletin Signaletique*, the

French abstracting service.

Immediately, after World War II, many governments and other agencies started realising the economic importance of information, especially in the context of specific projects. Also, around that time traditional boundaries between academic disciplines became blurred with the coming of hybrids such as materials science, systems analysis and mathematical biology. These led to the emergence of multidisciplinary and mission-oriented systems.For instance, the US National Agricultural Library established an agricultural information system, covering information for disciplines like agronomy, genetics, entomology, and fertiliser and pesticide technology. Likewise NASA developed a space information system covering many related areas.

In recent years the initiatives for producing STI delivery systems come from the governments themselves. The best known example is the computerised STI data bank set up at Vallbonne near Nice, thanks to the interest taken by the former French president, Valery Giscard d'Estaing, and his Secretary of State for Science, Pierre Aigrain. In India, we have set up the Indian National Scientific Documentation Centre under CSIR, and the National Information System for Science & Technology under the Department of Science &Technology, to help Indian scientists gain accessibility to worldwide information. The Government of India has also set up the National Informatics Centre under the Department of Electronics to deal with information vital for planning and development. Mexico, Bolivia and Morocco are also among the countries where such initiatives have come from the government.

Realising that the information business is profitable, many industrial corporations in the West have also entered the STI market, and produced not only primary journals, but also abstracting and indexing services and other bibliographic databases. Usually their products and services are much more costly than those provided by scholarly societies of scientists and quasi-government and government agencies. An example of an abstracting service produced by a publishing firm is the *Excerpta Medica*, the well-known biomedical abstracting service from Amsterdam.

The emergence of international cooperative mission-oriented STI databases is a recent development. One of the earliest such efforts was directed to providing information in the area of peaceful uses of atomic energy (INIS), and another dealt with growing more food (AGRIS). These are organised under the UN auspices. Participating nations have the responsibility to identify and contribute data generated within their boundaries, and are free to use the entire database which will be made available to them in return for the data they feed in. The philosophy of such equitable systems is "contribute what you have to the database and take whatever you need"—an indication of the realisation that information is a worldwide commodity to be used for the good of all mankind.

Since the beginning of the century, there has been a steady increase in the number of research scientists. There has also been a dramatic increase in the funds available for R & D from a variety of sources: governments, industrial corporations, foundations, etc. No wonder little science—the inquiry into nature by a curious few—grew into big science, a calculated attempt by large teams of scientists and technologists not merely to understand the workings of nature but to control and take advantage of it. One of the most visible consequences of this transformation was the exponential growth in the literature of science. For example, *Chemical Abstracts*, the world's most comprehensive database in chemistry and chemical engineering, which commenced publication in 1907, published its millionth abstract in 32 years; but the second million came in the next 18 years, the third million in the next eight years, the fourth million in less than five years, and the fifth million in a little over three years. Soon, it will be reaching the milestone of a million abstracts a year! Is it possible not to go in for computerisation?

So far we have considered the bibilographic databases useful in the retrieval of STI. But what about the production and distribution of the primary literature of science itself? Both the way journals are produced and the way the information content of the *journal* is packaged have undergone considerable changes with the advances in printing technology and with the scientific community's ever growing demand for more and more information in less and less space. The letterpress gave way to typewriter composition-cum-offset printing, use of word processors, photocomposition of text, and computerised composition of text-plus-laying out pages of text, visuals and tabular data, all at one go, using electronic video display units. Surface mail delivery gave way to accelerated surface post and airmail delivery. The language of science became more crisp and even unintelligible to anyone but the initiated. However, for the last three centuries the journal continued to be a print-on paper product.

The scientists prepared their manuscripts on typewriters and sent them by post to the editors of journals who in turn used the post office again to contact their referees and so on. And when recommended for publication, usually with suggestions for a few changes, a manuscript was returned to the author who would revise and retype it. It was typeset by a compositor, the proofs read, and the paper finally included in an issue of a journal.

But the compunications infrastructure of today has already started making inroads into the way journals are produced and distributed.

The electronic journal

The scientists of the future will use a keyboard, very much similar to that of an office typewriter, to type out—or "input" as they call it—their research findings. The entire manuscript will be transmitted electronically to a terminal at the editor's office. Even if the editor were to be away or if his office had a holiday, the message would be recorded. The editor will in turn flash the whole article, or parts of it such as a synopsis, again electronically to the terminal of a referee who will comment upon the cognitive content of the "paper". Of course paper as a material will be rarely used, though the term "research paper" will be allowed as a concession to nostalgia. When accepted for publication the paper will be stored in the computerised journal for any reader to recall on a visual unit of a terminal. The paperless "electronic journal" could soon replace much of today's paper-based journals, at least in science and technology. In the words of Wilfrid Lancaster, an award-winning professor of information science at the University of Illinois, "The library is dead. Long live the librarian."

Maybe soon, the science library as we know it today will go out of business. No scientist reads or needs to read the entire printed journal which carries between its covers a number of research papers. An example nearer home will put the point in perspective. The Indian Institute of Science, Bangalore, has one of the most active biochemistry departments in the country with over ten professors and about 50 research students at any given time. Their library subscribes to a number of the world's leading biochemistry journals such as the *Proceedings of the National Academy of Sciences, USA; Biochemica et Biophysica Acta;* and *Journal of Biological Chemistry*. Some of them are quite bulky. However, all the members of the faculty and students put together do not read even one-fourth of the articles published in any single issue of any of these journals. Each researcher reads only what is relevant to his work. Thus the printed journal, as it exists today, is a highly uneconomical means of disseminating knowledge.

With the advent of the electronic journal, it is possible for an individual scientist to use his terminal and call for only those papers which his study requires. With paper prices and printing costs escalating and with the communications technology bringing down the cost as well as raising the already fabulous capabilities of both the computers and the communications channels, the crossover point when the electronic journal will become the more economic alternative may be hardly a decade away.

Of course, science publishing is right now in a fluid state. The transition from the print-on-paper journal—which one can scan and browse at leisure, and carry in one's briefcase to read at home—to the totally electronic journal may yet take some time. Two decades say some experts, three or four is the estimate of others. Even then not all the flow of scientific information will be through terminals and computers. The paper journal might, by sheer inertia, fight a valiant battle for survival and might coexist with the paperless journals for decades.

Currently, about 450 computerised databases are available for on-line retrieval, which is not only more efficient and time saving but also considerably cheaper. It is obvious then that those who do not have access to the new technology are doomed to a second-class existence in the Republic of Science, where access to current information and speedy communication are the ruling currencies. It has been said earlier (SCIENCE TODAY, December 1979) and it bears repetition that the inability of Indian scientists to seek information relevant to their work is a major reason for their poor showing in world science, which is definitely incommensurate with the large manpower deployed and the huge funds spent on S&T.

We should modernise our communication system. Take the nightmares most telephone users in Indian cities now face. This should become a thing of the past. (The Central Government has recently initiated action to establish electronic exchanges in a number of metropolitan cities, even if it means a huge import bill.) The case is stated. Introduction of the new information technology will be beneficial to Indian science. Besides, there does not appear to be much of a choice. First should come the realisation that access to available information is vital for the growth of S&T. Steps should be taken to introduce the electronic means of seeking information, which is not possible without the widespread diffusion of the culture of electronics, computers and telecommunications. Unfortunately, this is one area where we have failed to achieve as much as we could have, in spite of having a full-fledged department and a commission headed by eminent technocrats. In the opinion of Kurt Hoffman of the University of Sussex Science Policy Research Group, India has a great potential in microelectronics, but "has no official development policy" with respect to that sector.

However, there are some plus points: (1) The Indian universities and institutes of technology train about 1,000 electronics engineers every year. (2) India's capacity in software design is well known—a leading Indian business house is even selling software packages to the West, and many Indian computer specialists are well placed in the US industry. (3) Bharat Electronics Ltd, a public sector undertaking, is already manufacturing integrated circuit chips, and a few firms in the private sector are producing computers of reasonable capacities though they import the all-important chips. (4) A national newspaper has been using facsimile technique, for over a decade, to produce multiple editions published from different centres spread over the southern states. (5) On more than one occasion, on-line retrieval of information from databases located outside the country (such as the ESA-RECON at Fraseati, Italy) has been demonstrated in India. The Computer Society of India has also demonstrated the feasibility of networking many computer centres in different parts of India (SCIENCE TODAY, March 1980).

It is not the scientific community alone which will benefit by the introduction of the new information technology. It can provide an opportunity for much of the Third World to leapfrog decades of industrialisation and be able to use advanced products of technology in their efforts to improve their industrial productivity, raise the overall literacy of the people at large, enhance the effectiveness of their educational institutions, and raise food production. The new information technology can be a great help in the planning and execution of national policies and projects. We will not go into them now.

Future shocks

The information revolution is a Janus-faced entity. On the one hand it has the potential to be the heart of the transformation of our civilisation. On the other hand, it is almost certain that it will have an essentially negative impact on the Third World, at least to begin with. Many of the future shocks are going to be microprocessor generated for the impact of information technology will be felt far beyond the realms of technology, in our polity, economy and society. In India, the first and the most obvious, of the problems will be large-scale unemployment. The rate at which microprocessor based technologies can create avenues for new jobs is an order of magnitude less than the rate at which it throws men out of jobs. This is already evident even in the West. The classical example is the entry of Japanese-made electronic watches into the world market in the seventies which at one stroke crippled the unrivalled Swiss watch industry. Forty-six thousand lost their jobs and 17 firms went bankrupt. Recently, a reputed Swiss watch manufacturer destroyed thousands of costlier models which they could never hope to sell. Already we see Japanese digital watches with liquid crystal displays (most of them smuggled) flooding the Indian market at prices much lower than those of the watches made in India. Japanese firms even take full page advertisements in mass-circulation Indian dailies displaying their latest handheld calculators, with a footnote "for information only"! Also, goods incorporating microelectronic devices require less labour than the ones they replace. An electronic cash register requires only 25 per cent of the labour that goes to make an electromechanical one. An electronic telex machine has just one microprocessor to replace 936 moving parts and takes about 18 hours to make as against 75 hours for the electromechanical one.

The introduction of the new technology almost brought *The Times* of London very close to writing its own obituary. The phenomenal pace at which cost-reducing and capability-enhancing advances occur in the new technology can only worsen the employment situation. The Japanese are ready with 64K (K for kilobit) random access memories and expect to market their 256K random access memories in a few years. The memories used now are in the 8K and 16K range.

The argument that technology has always created enough jobs to adequately offset the ones it makes redundant in the first place does not hold any more even in the advanced countries, what to speak of the Third World. The conventional argument of the protagonists of technology goes like this: Mechanisation and automation did not as a whole lead to unemployment but to a structural transformation of the economy, away from manufacturing industries to services. For instance, the fraction of people involved in agricultural occupations has steadily decreased with the application of improved technology—tractors, fertilisers, pesticides, hybrid seeds and so on. The workers released from agriculture did find jobs in factories producing different kinds of goods. Of course they had to learn new skills. With increasing automation, the labour force engaged in industrial production started to feel the pinch, but newer methods of producing mechanical energy and transforming materials were invented to keep much of the workforce occupied. Later on, the emphasis shifted from producing goods to providing services based on knowledge and managers, lawyers, professors, publishers and others came on. Larger and larger percentages of people acquired special skills and entered the knowledge industry.

In essence, the argument says that with the advent of communications, a number of people will find jobs as hardware and software specialists, programmers, laser technologists, etc and there will be a shift from traditional occupations to sophisticated information occupations.

But what this argument misses is that, even during the industrial revolution phase, jobs were not lost only within the countries where the revolution was unfolding. The suffering was felt elsewhere. The British textile industry hit the Indian weavers so hard that the resulting *Swadeshi* movement was as much an economic necessity as a laudable political instrument. It is not an exaggeration to say that the boom in production of goods made possible by the then new technologies and the consequent necessity to find a market did play a part in the colonisation of Asia and Africa by the industrially prosperous Europeans.

The crunch will be felt even more with the advent of the information revolution. As mentioned earlier, the deleterious effects on the employment situation has already been felt even among the members of the fraternity of the top industrialised countries. The giant automobile industry of the US has thrown in the towel and pleaded with the Japanese automakers to exercise volvoluntary curbs on exports to the US!

The information revolution differs from the industrial revolution in two distinct ways. It uses energy and materials, which are bound to be depleted with use, sparingly. Its strength comes from the maximal use of knowledge and information, whose supply is increasing exponentially and whose value is bound to increase and not diminish with use; as with materials and energy. With the introduction of labour-saving devices like the robots to perform routine industrial operations, the new revolution can take away from the Third World what are currently labour-intensive industries.

It is clear that those who enter the portals of the information society early will have opportunities to wield tremendous power. If the industrial revolution helped establish colonialism, the information revolution can help establish some form of acute economic and intellectual domination. An already unequal world will become even more unequal.

Questions germane to the information technology are: who has the information, who wants it, how can we get it, and what are the terms of trade? The answers do not come under the purview of technology but under *politics*.

Taking scientific and technological information as an example, Indian libraries in S&T institutions spend more than three-fourths of their books and journals budget on imports from the West. In fact, the literature produced within the country is precious little. Again taking chemistry as an example, an year's subscription for a single copy every week of *Chemical Abstracts* costs about $4,500. For an airmail subscription to *Current Abstracts of Chemistry* and *Index Chemicus* (which will bring two copies of each weekly issue), you pay about $1,000 a year. In contrast, for one subscription to CA Search, the computer readable file from the *Chemical Abstracts*, you have to pay about $9,100 plus a fee based on the number of times and the total duration the tapes are used. We in India are not only to pay for the databases we import but also for the equipment—the computers, the terminals, the telecommunication infrastructure—almost all of which will have to be imported, at least for a few years. Our electronics industry is still in the fledgling stage.

Take another perspective of the havoc information technology can play in India. Assuming we will equip each village with a computer terminal (as suggested by Jean-Jacques Servan Schreiber) and link them to a central network at New Delhi or the state capitals, hypothetically, the peasant farmer can have access to all the information required to ensure good family health, raise farm production and educate himself and his children. But in reality, how could the destitute poor and the illiterate majority actually use the information once it is provided? On the contrary, information technology can accentuate class divisions by creating a new class of the information rich.

This problem will be felt acutely in Third World countries where introduction of new technology has always aggravated existing social tensions. The much talked about green revolution led to the concentration of wealth in the hands of the rich farmers, considerably upsetting the power structure of rural India. The onset of mechanisation not only replaced the aristocracy of the British days with a class of *nouveau riche* but also resulted in an erosion in values, as elegantly portrayed by Satyajit Ray in his film *Jalsaghar*. It is difficult to predict what would be the consequences of the information revolution in a country torn asunder by economic disparities, acute political rivalries and problems of underdevelopment.

If we must use the technology to our benefit and not be harshly used by it, we must decide on a national information policy, taking into account our present strengths (software capability for example) and weaknesses and the needs of our society. The policy should not only talk about what kind of databases and technologies we are going to import (or generate locally) but also discuss how to minimise the culture shocks that are bound to accompany the new technology. After all, people are more important than technology and they are the *raison d'etre* for all technologies. The policy should start from the premise that we are a predominantly agrarian society (with over 70 per cent of the labour force engaged in agriculture) struggling towards becoming an industrial society, though there are a few pockets of affluence constituting a negligibly small component of the information society.

SUBBIAH ARUNACHALAM

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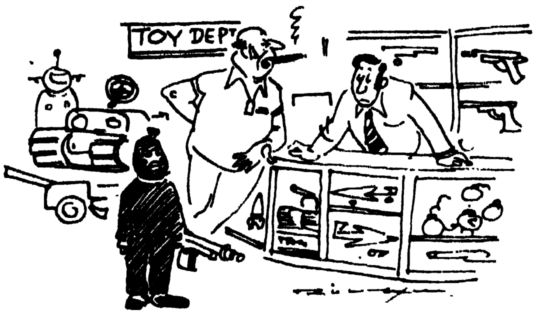
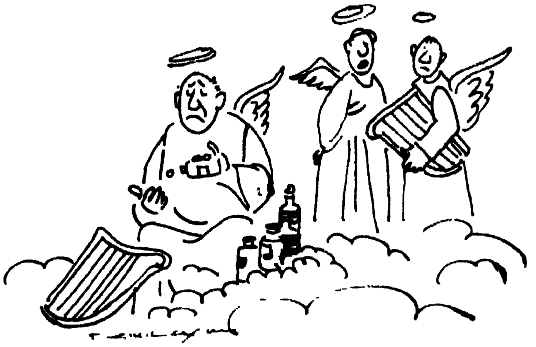
This World of Science!

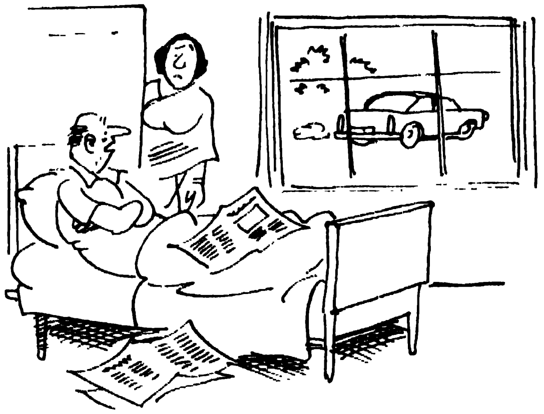
by R.K. Laxman



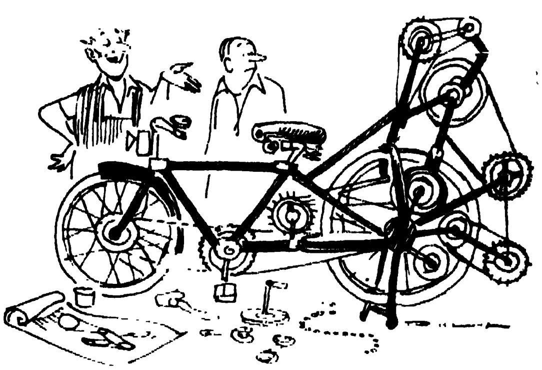
"Do you have a size smaller hood outfit please? He says it's too loose."



"Oh, don't bother about him. He was always a born hypochondriac."



"Yes, the doctor was here. We talked about inflation, the bomb, the price hike and so on. But I forgot to tell him about my excruciating stomach pain



"I have made it in such a way that it will give 5.6 kilometres more for the same energy."

...and of Scientists

THE father of the atomic theory, the Greek Democritus worked hard to persuade people against their beliefs in supernaturalism. Once, a citizen with a bare, bald head, met with an accident on the road. A tortoise had fallen upon his head and killed him. The people who gathered there, so the legend says, saw an eagle (believed to be a bird of the god Zeus) hovering over the dead body. They thought that the death was a 'divine portent'. When the rumour reached Democritus, he told them: "Eagles like the meat of the tortoise, but sometimes find it difficult to get them from the shell. They have, therefore, learnt to drop the creatures from a great height on shining rocks which shatter the shell and make available the meat. The eagle had simply mistaken the man's bald head for the splendour of rock".

Millikan

FEW people who knew R. Millikan as a student would have predicted for him a career in science. He was heading for a scholarship in Greek classics. One day while still studying for his degree, he was asked by his Greek teacher to take elementary physics classes. Millikan hesitated because he was not well versed in the subject. Noticing his hesitation, the old teacher told him encouragingly, "You have done excellent work all the year in my Greek class; I'll risk anyone who can do what you have done in that subject to teach physics..." And then Millikan had no option but to take to physics.

ROBERT LISTER performed his first successful operation under ether on December 21, 1846, in the University College Hospital, London. He had taken only 28 seconds. After witnessing the performance, the English surgeon James Simpson said: "This Yankee dodge, gentlemen, beats mesmerism hollow."

S. N. MUNSH

SCIENCE SHAPES LIFE

PRENATAL SURGERY: A NEW BREAKTHROUGH

Surgeons in USA have now carried out the first ever brain operation on a 24-week-old fetus, which showed signs of hydrocephalus. Hydrocephalus is a condition in which too much cerebrospinal fluid accumulates inside the skull. This causes the ventricles to enlarge, and in most cases serious brain damage results. About 0.2 per cent of babies suffer from this condition.

Today, hydrocephalus in a fetus can easily be detected using ultrasound monitors. And if detected, doctors wait for the birth of the baby before draining off the excess fluid using a minute tube inserted into the brain. In most cases permanent damage would already have been done, and the operation seldom succeeds in giving the child a normal brain.

The US surgeons, at Bringham and Women's Hospital and the Harvard Medical School, both in Boston, detected hydrocephalus as usual after a routine ultrasound check-up. They decided on prenatal surgery because they were sure that if left unchecked, it would retard growth. After studying the fetus with the same ultrasound scanner used on the mother, they chose an entry point for the minute tube at the site of a large ventricle, away from the baby's face and eyes. Using the scanner again to find their way, they inserted a 22-guage needle through the mother's abdomen, the wall of the womb, and the skull of the fetus to its brain tissue at the point where the fluid was collecting.

In 20 minutes, they had the excess fluid completely drained out, and they repeated the process half a dozen times over the next nine weeks. Gradually, the child's skull hardened. Whether the child born will be absolotely normal remains to be seen.

An 'ultrasound baby'

HANDS UPSY DAISY!
WOW! ..A..A REAL MUGGER
...INCIDENTALLY, I'M ON WITH MY PAPER ABOUT INSECURITY IN THE BIG CITY. HOW'D YA RATE YOURSELF BOY? AND HOW MANY BUDDIES HAVE YOU MADE LIKE THIS..?

MAKING FRIENDS IN A BIG CITY

Can living in a big city make a person lonely? Big-city life is characterised by impersonality, speed, and often apathy. But, can you have as many close friends if you moved to a big city the way you would in a small town?

It looks like you can. That's if you're one who likes to have friends, in the first place. Only, making lasting friendships in a city takes time, and after that things are just the same as in a non-urban setting—the results of a study by Karen Franck, an environmental psychologist and her colleagues at the City University of New York, USA.

The researchers interviewed 45 graduate students in a New York city college, and also 47 students at an equally important university located away in a small town (population 31,000). Both groups of students had more or less similar backgrounds, considering age, fields of study and previous experience of living in urban and non-urban settings.

Franck and colleagues interviewed the two groups twice. First, within two months of his or her joining college, and again, seven months later. At first it looked like the small town alone was fun. For, the non-urban group reported having about twice as many friends (average 6.3) as the urban students (3.5).

By the second interview, things had changed. The same students reported a figure of 5.3 and 5.1 respectively. Which implied that it takes time to make friends in the big city. Friends, as defined by the researchers, were more than mere acquaintances—people you do things with although you might not consider them close.

The researchers also tried to find out other things. For instance, most urban students attributed their delay in making friends to the "higher levels of fear, distrust and uncertainty aroused by meeting strangers in a big city". No wonder they were more concerned with "increasing vigilance and safety precautions". The non-urban group too reported obstacles in the way of friendship, many of them attributing it to "scheduling time better"

Another interesting find was that although both groups met their friends just as often, the big city group had their friends over to their homes more frequently.

WHY SALT CAUSES BLOOD PRESSURE

Haven't we been told that too much salt in our food may give us blood pressure. There is evidence for this, and in some cultures where salt is not used, hypertension is unknown. Yet, till now, nobody had any clue as to how salt worked to cause hypertension.

A hormone, called natriuretic hormone, may be the culprit, according to evidence gathered by many investigators. Natriuretic hormone increases the secretion of sodium ions into the urine, and there might be some link between excessive salt consumption and high blood pressure (*Science* **212** 1255).

There are some well-known agents that act as elevators of blood pressure, like for instance angiotensin and norepinephrine. But, a well-known researcher on hypertension, the late Lewis K. Dahl, suggested that there could be some agent distinct from these well-known ones. Dahl published this view in a report in 1969, but did not follow that up.

Evidence for the existence of natriuretic hormone first came from studies involving both animals and humans with excess blood pressure. Several researchers found that when the blood volumes of animals were increased, experimentally, it (the blood) contained a factor that increased sodium ion excretion by the kidney. Such a factor was seen in human blood as well, in patients suffering from uremia, an ailment when the kidney malfunctions and is unable to get rid of toxic materials and water from the body. There is mounting evidence that this factor is natriuretic hormone.

However, it may not be wise to eat tasteless food without any salt. For, salt may not cause most people any harm. Because, most of the investigators believe that by itself the hormone cannot cause hypertension, unless a person is genetically predisposed to develop the disease. And, incidentally, too much salt would be an amount in excess of three grams per day.

THE GREATEST STAR

So far the mightiest star known was HD 93250, a star in the Milky Way some 10,000 light years away and 120 times the mass of the Sun. The HD has now almost lost its title. The new champ is Radcliffe 136 (R 136). R 136 is ten times as luminous as HD 93250. It is in the heart of the Tarantula Nebula which is in a neighbouring galaxy called the Large Magallenic Cloud. It is 200 to 1,000 times heavier and 30 million times more luminous than the Sun. And its surface temperature is 55,000°C (the Sun's is 6000°C). The ultraviolet radiation from this superstar is enough to ionise the entire Tarantula Nebula.

Till recently, R 136 was thought to be a close cluster containing between 50 and 100 stars. But, according to observations by J.V. Feitzinger and T. Schmidt-Kaler at the European Southern Observatory (ESO), in Chile, the central radiation emitting source of Tarantula Nebula is less than three light years in diameter. This means the distance is too small to accommodate the postulated cluster of 50 to 100 stars. The ESO astronomers are double-checking to make sure it is a single object. Only then can R 136 be crowned.

Sea urchin sperms attaching to egg.

THE WINNING 'SUITOR' SPERM

The miracle of conception still remains an enigma. How does a sperm fertilise an egg? Researchers at the Johns Hopkins University School of medicine in Baltimore, USA, are looking for the answers. They are studying the process of conception in sea urchins, because fertilisation in these creatures occurs externally and is replicable in test tubes.

They've found that the sea urchin sperms bind to specific receptors on the surface of the egg (*top*). Yet, the chief mystery remains. Why does only one sperm out of thousands of them (*right*) get into an egg surface?All the others move away from the egg surface and die.

MULTIPLE SCLEROSIS: LOOKING FOR THE CAUSE

Giddiness, disorders in the coordination of body movements, in speech, sight and hearing, and paralysis, are all symptoms of a vicious disease suffered by about two million people in the world today. Described scientifically for the first time 129 years ago by a Frenchman called Jean M. Charcot, multiple sclerosis (MS) is apparently a type of civilisation disease. This assumption is based on the fact that it frequently occurs in countries with a high standard of hygiene. For instance, there are about 500,000 persons suffering from MS in North America, and some 100,000 in West Germany.

Despite intensive medical research it has still not proved possible to identify the causes of this disease, for which allopathy has no known therapy at present. For the first time at a scientific conference on this disease at Gottingen University recently, interest was focussed on the interaction of nerve and glia-cells. This interdisciplinary project, involving cytobiologists, geneticists, neurologists, physiologists, immunologists, pathologists, neurobiologists and virologists from six different countries, sought to reach a basic definition of this illness and to indicate further ways of conducting research into it.

In the case of healthy human beings, a fatty substance, rich in protein (known as myelin), covers the nerve fibres. Each segment of these fibres is completely embedded in lamellar myelin. The myelin's task is to isolate the nerve fibres electrically and to make the further conduction of nerve signals possible. If the isolation is missing, the propagation of the impulse is disturbed. The "oliodendrocyto-cells", each of which is allocated to a nerve segment, are responsible for the manufacture of the myelin.

In the case of MS, the myelin is destroyed and replaced by useless, "sclerotic" tissue. One of the participants stressed that, by means of physiotherapy, it is possible to achieve an improvement in the condition of MS patients, but that medicine is still unable to treat the basic damage. It still isn't known what actually causes multiple sclerosis. The intensive search for an MS virus has, admittedly, revealed that MS patients possess antibodies against viruses which one does not find in normal patients. But not one of these viruses has turned out to be the illness causer. Even so, the hypothesis that a virus could play a part is still not being ruled out.

Further research is being facilitated by the fact that it is now possible to trigger off chronic illness in animals which are similar to MS and which, as a consequence, permit scientists to examine partial aspects of MS problems by means of animal tests. A substance has also been found through which the oliodendrocytes can be selectively destroyed. Another substance destroys the myelin lamellae produced by the oliodendrocytes. These seem to constitute "enormously potent working models"

One pointer to the cause of MS may well be found in the incidence level of this disease since it differs from region to region. A striking feature, for instance, is the fact that, in relation to the size of population, the Orkney Islands have the greatest number of MS patients in the world.

Be that as it may, medicine is still a very long way off a basic definition of MS.

This doesn't mean, of course, that methods of treatment have not been improved over the years. Observations made on some 2,000 patients over the last 20 years have shown that there are a good number of non-malignant MS cases. After all, some 30 per cent of these patients are pursuing a profession. An estimated 10 per cent are suffering from the non-malignant variety of MS which makes its presence felt only intermittently. Only about four per cent of the MS cases are actually malignant, leading to death within a period of five years. Happily, life expectancy of MS patients has doubled in the last 40 years.

POOR SLEEP DOESN'T MAKE YOU TIRED

Poor sleep, or what one considers a "short night", is not the reason for tiredness, or the feeling that one's output is consequently impaired during daylight hours. It is, apparently, the negative attitude to being awake which is the cause. People with sleeping problems which cannot be attributed to a specific cause or important attendant factors seem—according to the findings of psychological tests—to be excessively concerned with themselves. Their worried thoughts centre too much on their own person, and their own mental and physical well-being. Less sleep does not, as is so often assumed, automatically lead to a drop in personal performance.

Investigations conducted by psychologists in Munich was provided by 400 patients who had responded to an article in a city newspaper on the treatment of sleeping disorders. Eighty-six of them, aged between 20 and 55, complaining solely or mainly of the inability to fall asleep to a point of feeling ill, were examined more thoroughly. The result: 56 of them displayed conspicuous psychic behaviour and personality patterns, a good three-quarters stated that they felt tired and short of sleep during the day, and 65 per cent were consequently of the opinion that their waking hours' output was negatively influenced as a result.

In point of fact, poor sleep seems to be a combination of difficulties in falling asleep, waking up during the night, shortened sleep and the personal feeling of having had a "bad night". Contrary to the assumption on the part of most patients, however, disturbed sleep is not only governed by actual length of sleep. On average, the 86 persons stated that they slept about 5.3 hours but would have preferred to sleep two hours longer. In the case of persons not complaining of sleeping disorders, the difference between actual and desired sleep comes to no more than one hour. This discrepancy, according to one estimate, can be traced back without difficulty to the "systematic" overestimation of the actual duration of sleep by the "sound" sleepers, and underestimation by the "poor" sleepers.

JUTE REPLACES FIBRE GLASS

Jute reinforced plastics (JRP) is a new appropriate technology developed in Bangladesh.

Eighty-five per cent of Bangladesh's foreign exchange earnings come from jute. The jute industry there employs 200,000 wage earners and provides cash incomes for 10 million farm families. However, in recent times the jute industry in Bangladesh has faced heavy competition from synthetics. And the JRP seems to have saved it (*Appropriate Technology* 7 4).

JRP represents a unique breakthrough that combines modern structural technology with locally available material and labour. The result: a low-cost construction material suitable for construction of schools, clinics, warehouses and even homes that can withstand cyclones, heavy monsoons and the hot sun, common weather conditions in Bangladesh.

But, in Bangladesh, perhaps the greatest boon provided by JRP will be its potential to supplement the scarce timber and expensive reinforced cement concrete.

Initial tests with JRP promises that it will be a good substitute for fibre glass, JRP having 82 to 90 per cent of the strength of similar fibre glass reinforced specimens. A load test showed that JRP could withstand a pressure of about 2.5 kg per sq cm on horizontal area.

It may soon be possible to extend the technology to cotton or sisal in place of jute in other countries where these are more abundant.

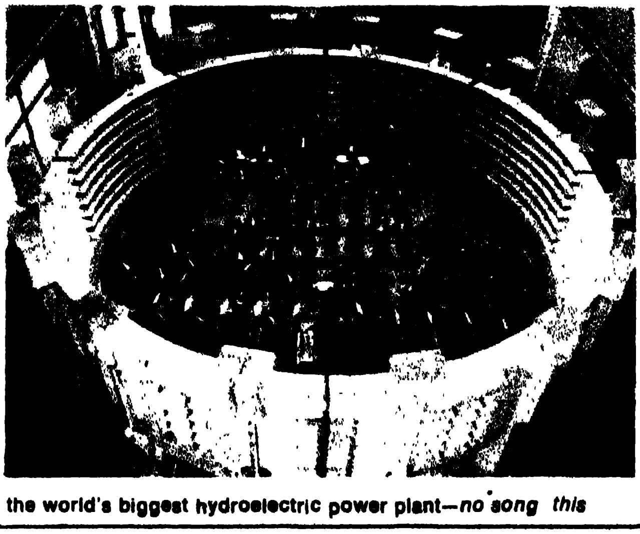
ITAIPU: A PROJECT OF SUPERLATIVES

The largest and most powerful hydroelectric power station in the world—a Brazilian-Paraguayan joint venture—is to be in full operation from 1988.

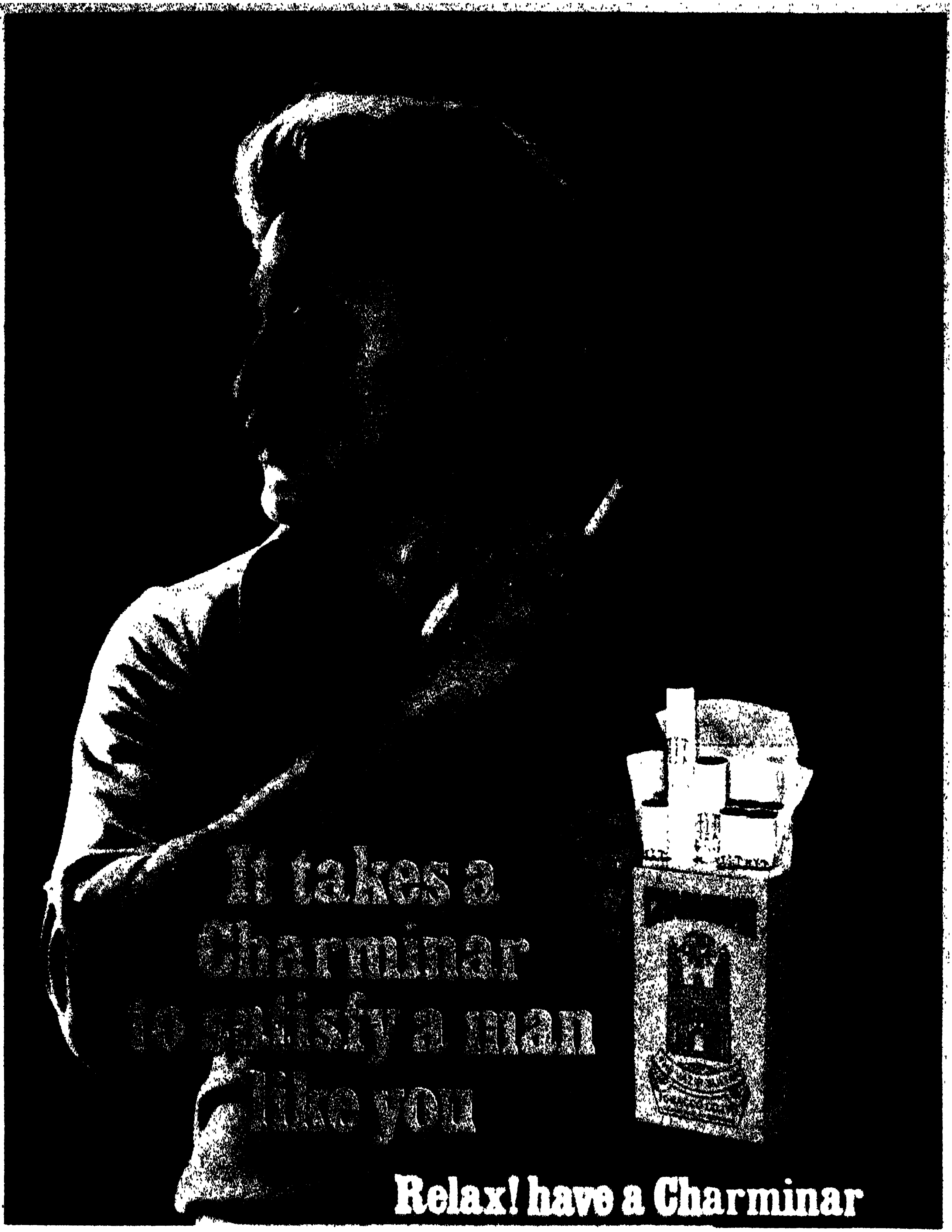
Superlatives apply to this structure in every respect. Itaipu, by far the largest and most powerful hydroelectric plant in the world, represents the project of the century for two Latin American countries in their determined drive to tap and utilise the gigantic reserves of their continent's water power. This mammoth project on the Rio Parana is to be completed by the end of 1988. The power station will then supply 75,000 million kilowatt-hours of electrical energy year after year.

For this, 18 generator sets will be in operation. The ratings of the Itaipu generators, each one of which has a diameter of about 20 metres and weighs far more than 3,000 tonnes, exceed the equivalent specifications of almost all water power machinery installed to date.

What you see in the photograph is not, as one might think, a new kind of orchestra pit, or a concert stage of futuristic design. The wide ring in which the entire symphony orchestra of Sao Paulo, with its 80 musicians and all their instruments, has ample room, is part of a hydroelectric generator. The picture gives an impression of the gigantic dimensions: The stator that has been "borrowed" for the picture here is about six-and-a-half metres high, with a diameter of almost 20 metres. Upon completion, each of the generators will weigh well over 3,000 tonnes. Brazil's power requirements, which are increasing by ten per cent annually, make it necessary to accentuate the use of nuclear power and to tap the country's hydroelectric potential.



Stator for the world's biggest hydroelectric power plant—*no song this*



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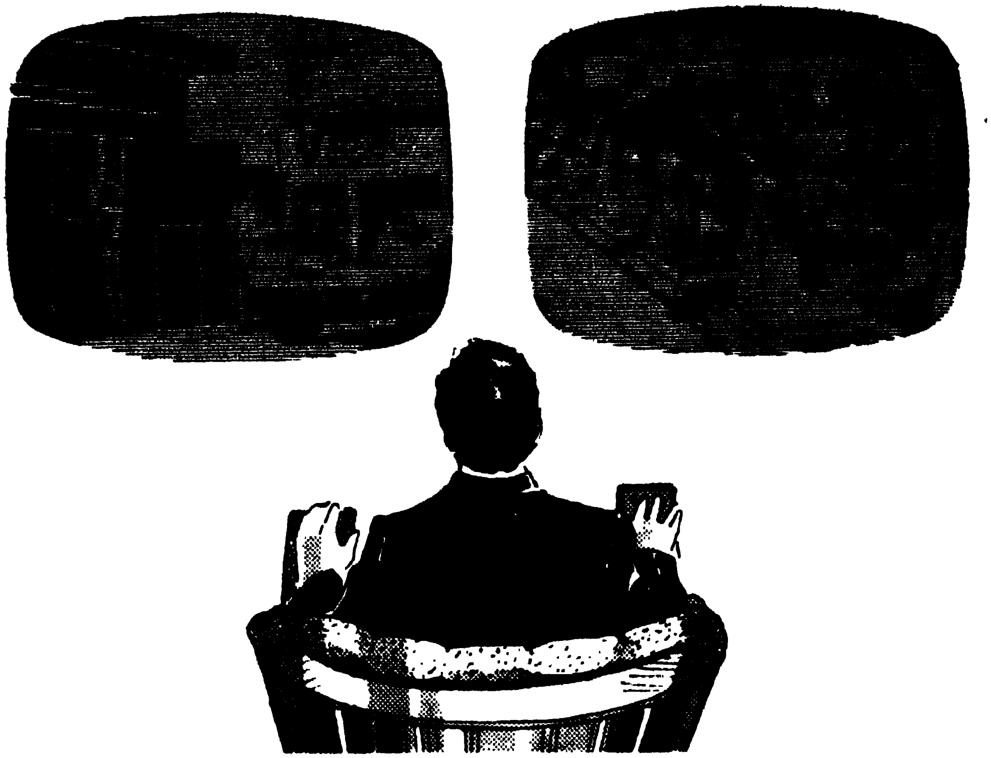

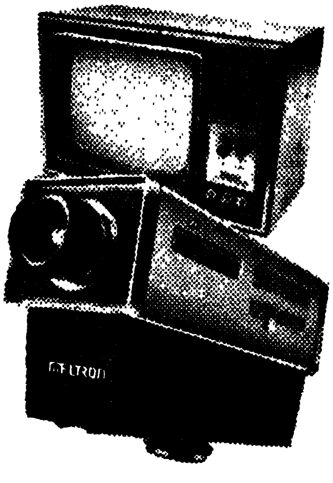

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CHAITRA-ME-95-R

Biomass: an alternative energy source

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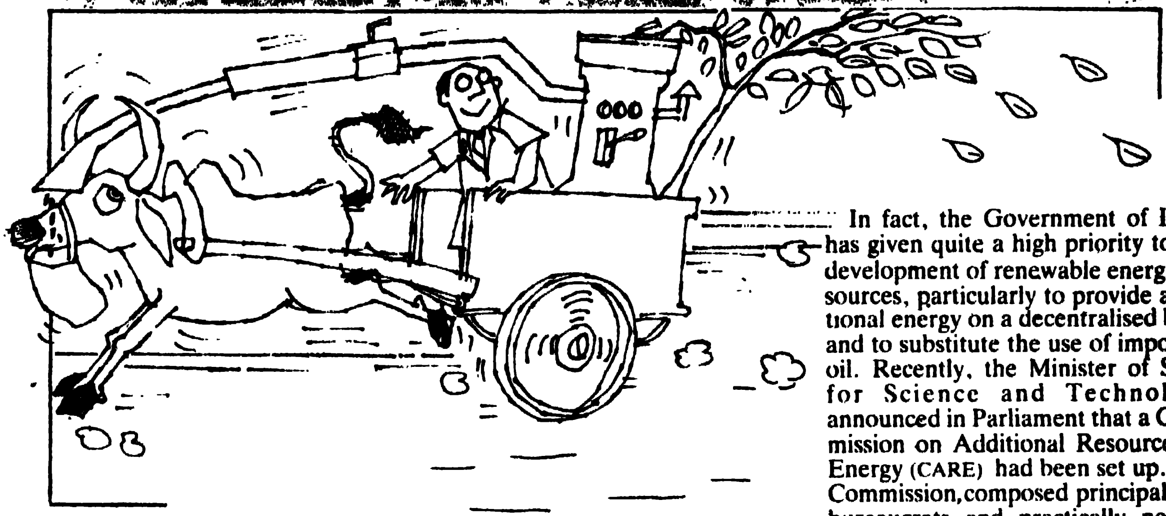


EVERY year plants store about 10 times the energy the world now consumes annually. Photosynthesis, by which plants convert solar energy to biomass, uses only a small part of the Sun's energy to fix 200 billion tonnes of carbon into terrestrial and aquatic biomass with an energy content of 3000 billion giga joules every year. At any one time biomass stores as much energy as all the proven reserves of fossil energy sources—coal, oil and gas —put together. Yet, even today, only one-seventh of the world's total energy comes from biomass use. A large and renewable resource is thus left largely untapped.

But it can be put to work for us, and this is something in which nations—particularly developing nations—that have little oil resources, are now beginning to get interested. This month's UN Conference on New and Renewable Sources of Energy at Nairobi should yield some useful solutions to the energy crunch that will involve greater use of biomass energy.

There are also other compelling reasons why biomass energy should be exploited. Besides contributing significantly to the country's energy resources, biomass can provide a wide range of chemical feedstocks for the organic chemical industry, which now come from petroleum sources. Biomass, by contrast to fossil sources, gives clean energy and its wider use will result in a cleaner environment and prevent ecological imbalance. To a large extent, it will also solve soil erosion problems.

But for a successful biomass energy programme, adequate biomass resources and specific technologies to convert them into energy are essential, not to mention the availability of institutional facilities for training manpower in the field of biomass conversion and biotechnology; more so, for a developing country like India. Eighty per cent of the country's population lives in rural areas and nearly 44 per cent of our total energy use is based on biomass; we will continue to be dependent on biomass energy resources.

In fact, the Government of India has given quite a high priority to the development of renewable energy resources, particularly to provide additional energy on a decentralised basis and to substitute the use of imported oil. Recently, the Minister of State for Science and Technology announced in Parliament that a Commission on Additional Resources of Energy (CARE) had been set up. The Commission, composed principally of bureaucrats and practically no experts, will have powers to make and execute policies relating to renewable energy resources. The country will, therefore, be watching with interest what the CARE will be able to achieve

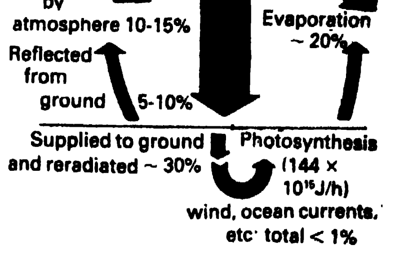

Solar radiation entering atmosphere (622,800×10¹⁵ J/h)
Reflected from atmosphere ~ 30%
Absorbed by atmosphere 10-15%
Evaporation ~ 20%
Reflected from ground 5-10%
Supplied to ground and reradiated ~ 30%
Photosynthesis (144 × 10¹⁵J/h)
wind, ocean currents, etc total < 1%

Fig. 1 Solar energy flow and its contribution to biomass production

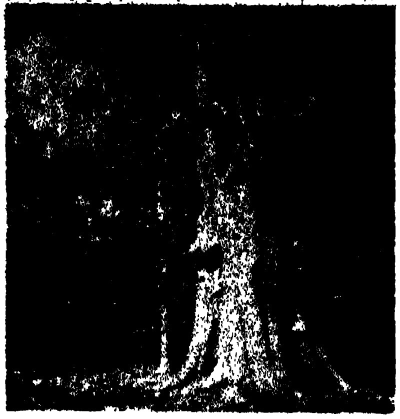
Biomass, strictly speaking, is the overall plant matter which is created by photosynthesis in which the Sun's energy converts water and carbon dioxide into organic matter. The latter is mainly made up of cellulose, hemicellulose and lignin. Aliphatic organic building blocks are derived from cellulose and hemicellulose, while lignin can be converted into almost every type of aromatic downstream products. By extension, biomass can also be taken to cover livestock droppings, since these are derived from plant tissues.

The entire organic content of the biomass can be converted into available forms of energy. The most obvious example is firewood which is still one of the most widely used fuels in our country. Fossil fuels were also derived from biomass since they are the fossilised remains of plants that grew some million years ago.

However, on any time scale of current interest these represent a non-renewable energy resource. Organic substances, like fossil resources, can be converted into almost every kind of chemical derivatives and synthesis products. Such products include solid, liquid or gaseous fuels, produced by both chemical and biological processes.

Photosynthesis and biomass formation

Photosynthesis is a perpetual but complex process by which plants use solar energy to transform the low-energy carbon dioxide into energy-rich organic compounds. It is the basis of all food chains; it also provides our bodies with all the oxygen that we need. Oxygen in most food plants, however, has a profound effect of diminishing potential crop yields by the process of photorespiration. In photosynthesis the presence of oxygen leads to the formation of glycolic acid by an alternative pathway which results in some of the carbon being burnt off as carbon dioxide. This is photorespiration and it may even burn off up to half of the carbon which would otherwise yield more plant biomass. If photorespiration were minimised it could lead to a large improvement in crop yields. Studies in the US and UK now provide a unanimous 'yes' to the basic question in photosynthesis research; can photosynthesis further increase biomass yields?



Photosynthesis in some plant species occurs through the C_3 system for photosynthesis, so called because it uses a three-carbon skeleton for biosynthesis. Rice, barley, alfalfa, wheat, cotton, soyabean, peanuts, sunflower, etc are typical C_3 plants. Other species that are especially adapted to higher temperatures to fix carbon dioxide by photosynthesis but lack photorespiration are known as C_4 plants; they use a four-carbon skeleton. These plants (sugarcane, sorghum, maize, etc) can fix more carbon dioxide with much less or even no photorespiration. They are, reportedly, also more tolerant to high temperature than the C_3 plants. This mechanism allows the plant to overcome the oxygen-dependent inhibition seen in most temperate plants. Sugarcane can thus produce the highest yield per hectare of any cultivated crop due to its combined characteristics of the C_4 photosynthetic pathway, a long-growing season and indeterminate growth habit.

While most green plants require sunlight to fix carbon dioxide, many species native to deserts have evolved a third system for fixing carbon dioxide at night—the Crassulacean acid metabolism (CAM), so called because it was discovered first in the *Crassulaceae* species. Such plants can drastically reduce water loss since they can keep their stomata closed during periods of high temperatures and insolation. Therefore, CAM plants such as pineapple and century plant are particularly well adapted to arid climates.

So far, only a few plant species have been characterised with respect to their photosynthetic systems. This is essential to evaluate cropping requirements. The biomass and the energy yields of some selected plant species are shown in Table 1.

Let us consider the effects on the environment of using biomass energy, for, the effect of an energy system on the environment is equally important. In the last one hundred years, the carbon dioxide concentration in the Earth's atmosphere has increased by about 30 parts per million (ppm) to an average of 320 ppm; it is believed that this has been caused only by the increased fossil fuel usage. In the last decade alone, the carbon dioxide concentration has increased by about 10 ppm. We don't yet know how the increased carbon dioxide in the atmosphere is going to affect the climate. Some believe that it could have a "greenhouse effect" Carbon dioxide being opaque to infra red, would reflect back the solar radiation that is normally reflected back into space by the Earth and gradually increase the temperature of the Earth's surface. A temperature rise of only a few degrees could warm the upper layers of oceans and cause a rise in the sea level; the cultivated areas would shift towards the Earth's poles, and probably the polar ice caps would melt.

We can avoid all this by burning biomass, or synthetic fuels derived from it. It would not alter the ambient carbon dioxide concentration if the biomass consumed were replaced by short-term growth of

new biomass. Since plants draw their carbon dioxide from the atmosphere, biomass use would simply restore this carbon dioxide to the atmosphere. Thus, no *new* carbon dioxide would then be added through biomass-to-energy systems. All operations would be carried out above the surface of the Earth, leaving the carbon dioxide level of the atmosphere undisturbed.

Biomass energy is thus, environmentally, a very acceptable resource. The wider use of biomass for development, therefore, would result in a cleaner environment, offer minimal ecological imbalance and provide the means to recycle nutrients and carbon dioxide from the atmosphere.

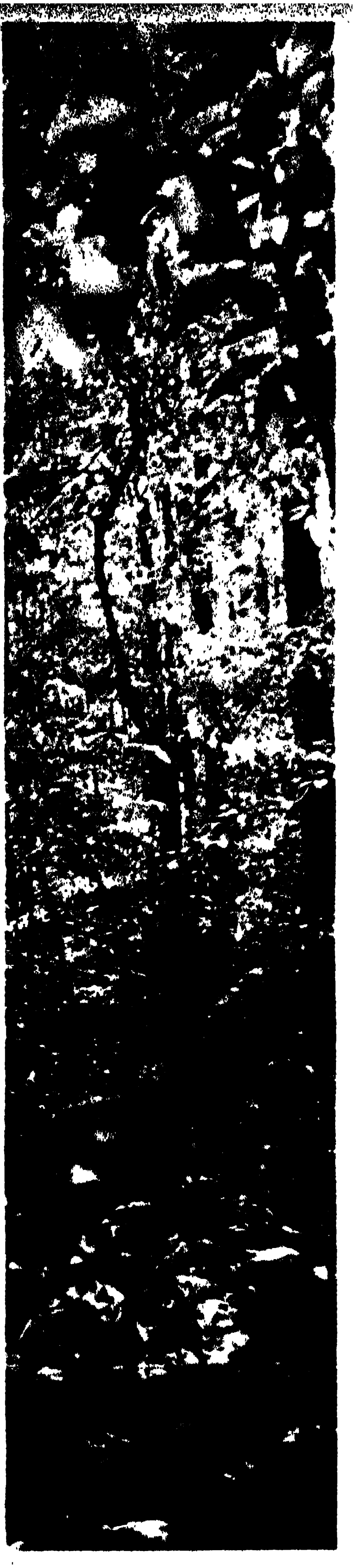
Biomass resource base

Biomass thus includes both terrestrial as well as aquatic matter that may be burned or converted into fuels. It can be grouped into three broad categories—new plant growth, plant residues and waste. New plant growth includes wood, short-rotation trees, herbaceous plants, conventional crops as well as fresh water and marine algae, and aquatic plants. Residues include not only crop materials such as straws, husks, bagasse and corn cobs but also animal droppings and forest or wood-based materials like bark, saw dust, shavings and roots. Waste comprises materials which must, normally, be disposed of at some cost—like garbage, night soil, sewage solids and industrial refuse.

Residues and wastes

Biomass resources include agricultural and forest residues. Of these, the availability of agricultural residues, such as rice husk and straw, is related to agricultural productivity. In India, the availability of the major components of these residues is of the order of 204 million tonnes annually. Of the total area of 75 million hectares already under forests, 45.6 million hectares (60 per cent) are being used and another 14.8 million hectares (20 per cent) are potentially exploitable. According to the 1969 Indian Forest Statistics, the growing stock of forests alone is estimated at 2 billion tonnes; of this, the forest residues consisting of leaves, branches, tops of felled trees, thinnings, etc are of the order of 3.3 million tonnes.

A large number of organic chemical industries produce liquid effluent,a major part of which is biodegradable, and could become a sizable biomass resource base. Food processing industries, canneries and freezing plants, sugar mills, slaughter houses, meat packing plants, tanneries, breweries, distilleries, etc can all provide such effluents.



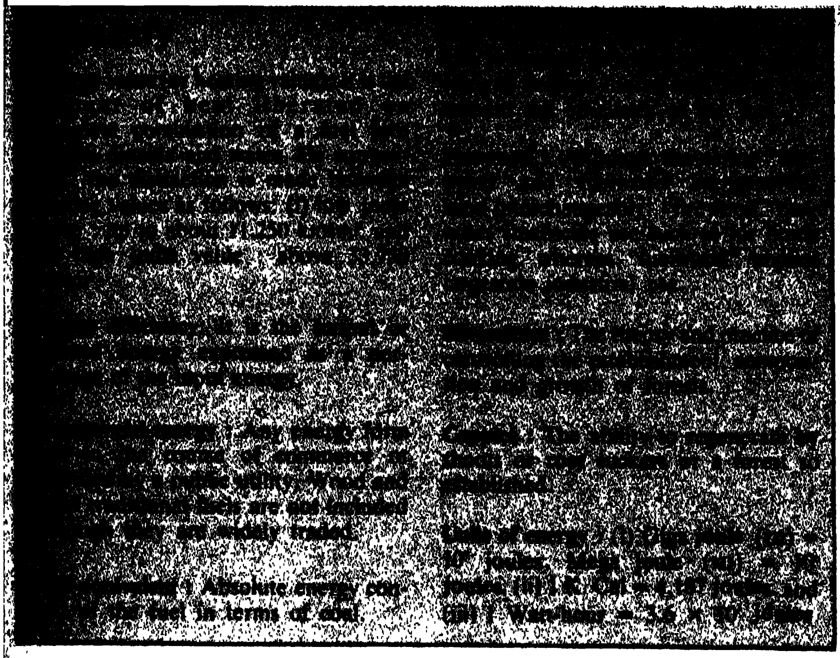
Night soil, another material that today largely goes waste, when supplemented by nearly 25 per cent dung and 25 per cent aquatic biomass like water hyacinth and algae, and by agro-residues like rice husk or straw, could become a massive renewable feedstock for a steady supply of biogas to the rural community. This can also become a radical way of solving our severe rural sanitation problems. However, handling night soil is not an elite job and so this large and stable resource continues to remain unexploited in India.

By contrast, China has demonstrated its successful use in a big way. China has over seven million biogas plants (India has about seventy thousand) which use biomass feedstock in the form of agricultural, animal and human residues — animal manures, human faeces and urine. The system is not only a good approach to solve the fuelwood crisis in China but also provides a soil conditioner which increases food production. It even reduced diseases, due to a hygienic disposal of night soil and the destruction of pathogens, by up to 90 per cent in some areas. Low cost digesters costing about Rs. 250 (about $30) have been built to suit local conditions and to bring them within the financial reach of an average Chinese family.

Animal dung can become an important resource in India, too, providing India with energy in the form of methane (popularly known as biogas) for, India has nearly one-fifth of the world's bovine population—about 175.6 million cattle and 52.9 million buffaloes. The average output of their wet dung is around 1.3 billion tonnes per year. If this were used for biogas production, the gas, about 152 million cubic metres (3.4×10^6 giga joules), would be equivalent to the total quantity of kerosene consumed in the country (valued at Rs. 113 million). Additionally, 1.5 million tonnes of organic manure will also be available from this dung, which is approximately 39 per cent of all the total synthetic nitrogen-phosphorus-potassium (NPK) fertiliser used in the country in 1980-81.

Energy forests

Farm forests, an important biomass resource, can go a long way to resolve our present fuelwood crisis, for the demand for fuelwood has grown far faster than its supply. The magnitude of this fuel crisis is immense. Forests in developing countries are being consumed at a rate of 1.3 per cent of the total forest area, or 10 to 15 million hectares per



year. This problem is most serious in semi-arid and mountainous areas where, as fuelwood supplies are exhausted, even animal and crop residues have to be burned, depriving the soil of valuable nutrients and organic conditioning material. Yet, technically and economically sound means already exist both for reforestation and for improving the efficiency of burning wood and other fuels.

About 50 million hectares of fuelwood would have to be planted in the developing countries by the year 2000 to satisfy the projected demand for domestic cooking alone. If the pace of tree planting around the world is not greatly accelerated, then, says a World Bank report, "by the turn of the century, at least a further 250 million people will be without wood fuel for their minimum cooking and heating needs and will be forced to burn dried animal dung and agricultural crop residues, thereby further decreasing food crop yields". In Asia (including India), where serious erosion problems have already occurred, we should not be satisfied with merely increasing the total planting. Special efforts must be made to combine these increases in planting with measures to control erosion.

Little attention has so far been paid in India to growing wood for energy purposes. Fast growth and high yields are the most important criteria for energy plantations. Selected species of immature trees of between five and 15 years growth are considered suitable feedstock for fuel production. Two different methods, single-stem trees and "coppicing", can be used in growing trees for energy purposes. Single-stem trees are already being used for most commercial wood production. Both thinnings and residues from commercial forests, and single-stem trees grown on farm forests, especially for high short-rotation yield, are important.

In coppicing, trees are encouraged to grow with several, rather than one, main stem. Coppiced trees are the result of a particular management practice. Established coppice grows much faster than single-stem trees in the first years of growth. It can be repeatedly cut down to the ground and still grow again. Important species of fast-growing trees in India for coppice plantation are *Populus* (poplar), *Nothofagus* (southern beech), *Alnus* (alder), *Salix* (willow), *Eucalyptus* (gum), etc.

Cropping energy

Energy crops are another important biomass resource. Plants that have good potential include sugarcane, sweet sorghum, cassava, soyabean, sunflower, euphorbia, woody plants, napier grass and the water hyacinth. The concept of silvicultural energy farm (short-rotation tree farm) can be used to optimise the output of these plants. Production of silvicultural energy crops may require a smaller input of resources and energy than conventional farm crops for comparative yields. In Ireland, for instance, short rotation forestry has been selected as the most suitable energy crop. According to the Irish estimates, energy crops can give annual energy savings (at 0.37 tonne of oil equivalent (TOE) per tonne of dry wood) of 3.70 million tonnes on 800,000 hectares of land as a result of a 20 year-planting programme; this corresponds to an increase of 80 per cent of savings in TOE in this period.

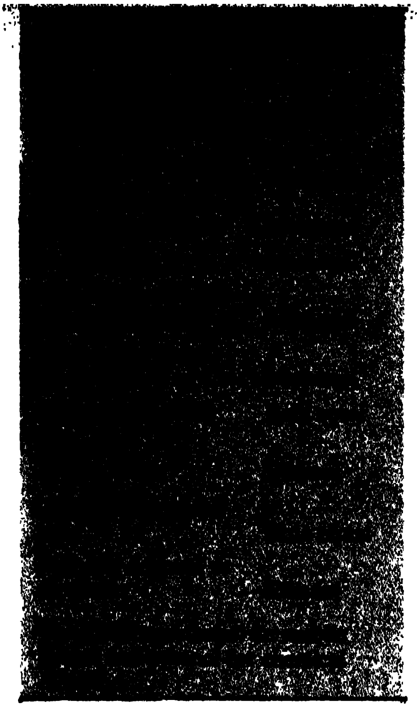
Hydrocarbons and oils for energy

Plants such as *Euphorbia, Guayale, Ascelpices* (milkweed), *Jojoba* and *Apocynaceae* (dogbene) produce complex products such as latex, waxes, resins, terpenes and several hydrocarbons, which could replace petroleum as a source of chemical feedstocks. Jojoba bean oil, for example, can substitute for spermwhale oil in cosmetics, drugs, plastics, industrial lubricants and waxes. These hydrocarbon plants would grow mainly in semi-arid regions without competing much with food crops. Organised plantations of euphorbia can even yield as much as 25 barrels of hydrocarbon oil per hectare per year. Babasu fruits yield 1 to 3 tonnes per hectare per year.

Edible and non-edible vegetable oils can also be used as fuels, particularly for diesel engines. They can be extracted from a multitude of plants—from legumes (soyabean and ground nuts), palms (oil palm and babasu) and nuts (sunflower) and also from castor bean, tobacco seed and rape seed. Because of their use as edible oils and their shortage, it is important to search for non-edible oil plants for energy purposes; some of the important varieties are neem *(Azasdirachta indica)*, mahua *(Madhuca indica)*, kusum *(Schleichera trijuga)*, sal *(Shorea robusta)* and kokum *(Garcinia indica)*. Non-edible oil seeds can be used in the manufacture of soap,

Table 1. Dry biomass yield and energy equivalent of selected plant species

Species	Tonnes/ hectare/ year	GJ/hectare year



fatty acids, etc. Some can also be processed into edible products. Neem cake, the residue left after extracting oil from seed is an excellent fertiliser, several times richer in plant nutrients than manure. The Brazilian experience (see box) is a good, case which deserves trial in India.

Sunflower seed oil is a highly suitable extender of diesel fuel. South Africa, for example, produces 400,000 to 500,000 tonnes of sunflower seed a year, mainly for cooking oil, margarine and animal feeds. Currently 4.3 million hectares of maize are planted but with improved agricultural practices, the same yield can be produced on about 3.0 million hectares, releasing 1.3 million hectares for the production of sunflower seed oil, giving nearly 600 litres of sunflower seed oil per hectare.

Since the oceans cover about 70 per cent of the Earth's surface they receive most of the solar energy reaching the Earth. Marine plants such as water hyacinth, kelp and duckweed can of course give fuel in the form of methane, ethanol and hydrocarbons; besides, they can also be used as fertiliser and as a source of chemicals. Ocean farms are therefore another pathway to biomass energy.

Many potential biomass feedstocks have been identified and the possible routes of their utilisation are now fairly well established (Table 5). The possible combinations of biomass feedstock, conversion technologies and end products are, however, too numerous to be considered here, hence our detailed discussion will be confined to two important alcohols—ethanol and methanol—and methane, the energy component of biogas. Ethanol and methanol are also quite suitable as a source of chemical feedstock for a wide variety of downstream products which are today derived from natural gas or naphtha.

The total energy contained in some selected biomass resources (Table 1) indicates that a major portion (about 57 per cent) of the commercial energy demand during 1987-88 (estimated at 500 million tonnes in terms of coal replacement) can be met by these resources if production is organised properly, mainly through bioconversion routes.

Extracting energy: thermochemical conversion

Technologies to convert biomass into energy fall into two general categories—thermochemical and biological. Thermochemical processes use high temperatures to convert biomass by direct combustion, pyrolysis, gasification and liquefaction. By contrast, biological processes involve enzymatic breakdown of biomass by micro organisms at low temperatures and pressures.

Table 2. Major potential biomass resources

[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	26.1	[illegible]
[illegible]	2.1	[illegible]
Coconut husk and shell	1.0	[illegible]
Oil-seed cakes	6.7	[illegible]
Sawdust	3.0	[illegible]
Cattle dung (wet)	1335.0	[illegible]
Forest products/residues		
Mahua flower	1.0	[illegible]
Leaves, tops etc	3.3	[illegible]
Total	15[illegible]	[illegible]

Many more residues/by-products are [illegible] able in scattered manner which have [illegible] been included here.

Table 3. Biomass to biofuels status—production and conversion

	Time frame of impact	Status/ comment
Biomass resource		
Agricultural and forest residues	Immediate	Commercial
Short rotation forestry	Short term	Demonstration
Other energy crops	Immediate to medium	Demonstration
Feedstock preparation	Immediate	Commercial
Industrial effluents	Immediate	Commercial
Aquatic biomass for [illegible]anation	Short term	Pilot plant, fresh water systems
Hydrocarbon plants	Medium term	Research to pilot plant
[illegible]ologies		
Thermochemical		
[illegible]	[illegible]	[illegible]
[illegible]	Short term	Demonstration
Gasification		
low heat value gas	Immediate	[illegible]
high heat value gas	Short term	Demonstration
[illegible]	Beyond 2,000	Process [illegible]
Bio[illegible]		
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

[illegible] term [illegible] plant [illegible] and [illegible]

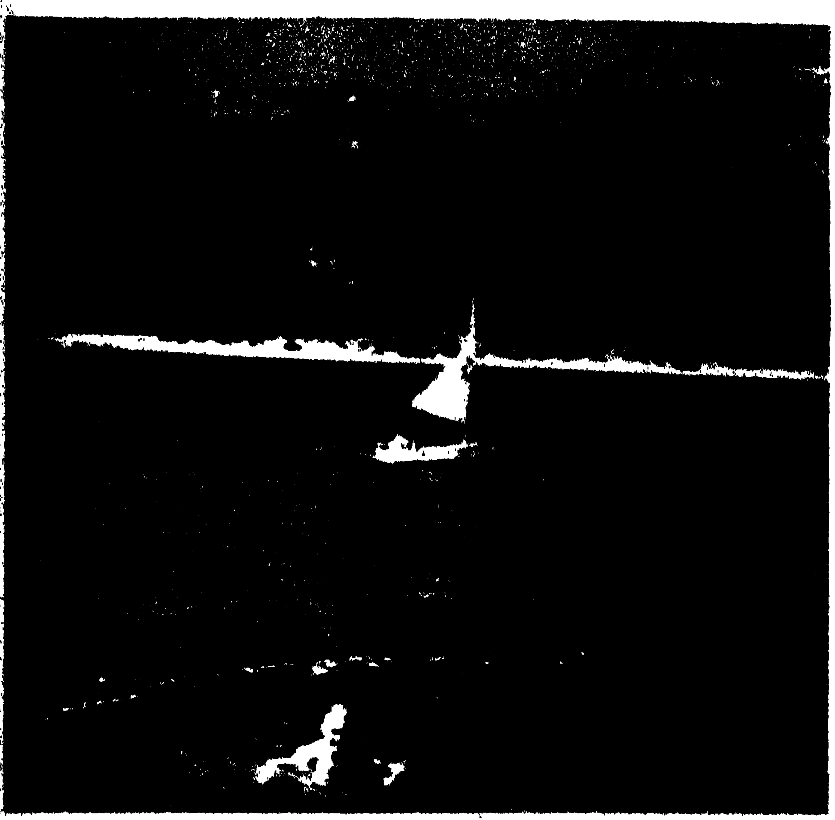
Direct combustion

In direct combustion, the hydrogen and carbon in a fuel combine with oxygen, a process which releases heat. This is the most common thermochemical method of converting biomass to energy. Biomass burns in three successive but overlapping stages, first, the contained water evaporates, then there is distillation and probably combustion of volatiles and finally the high temperature reaction of fixed carbon with oxygen. Only the last two steps release heat and provide us with energy. Direct combustion of biomass provides the majority of the rural population of the world with energy for cooking and heating. Wood is burnt daily in a variety of ways all over the world—in open fires, simple cooking stoves, Dutch ovens, and sophisticated package boilers and fluidised bed units.

Open fires, widely used in India, deliver only 5 to 10 per cent of the available energy for cooking. The efficiency of wood burning stoves can be increased to an overall efficiency of between 20 and 30 per cent. This will reduce not only requirement of fuelwood by 5 to 10-fold but also the time, energy and money that the Third World population now has to spend on collecting fuel and occasional explosions. Direct combustion units, which allow up to 80 per cent energy recovery, can be built. Production of charcoal from wood, as well as briquettes, pellets and chips of wood and of agricultural and other plant residues can further save energy.

Besides these traditional uses, direct combustion is industrially used for generating steam and electricity. However, direct combustion of biomass often requires carefully tailored equipment to satisfy the constraints imposed by the properties of biomass feedstocks. High ash fuels for instance can lead to slaggering in boilers. The heating value of the biomass may also be low due to high moisture and ash contents. Variation in feedstock composition and size distribution also creates difficulties in controlling combustion. Finally, biomass causing high corrosion or erosion will require special materials of construction.

Fig. 2 Swimming in reclaimed sewage. The Indian Creek reservoir in California, USA is filled entirely with reclaimed sewage water, not only safe to swim in, but also to drink



Everyday, municipal, commercial and light industrial wastes are converted to energy in about 450 mass burning facilities throughout the world by direct combustion. Over 99 per cent of the world's solid waste is processed into energy by a mass burning, refuse-fired energy system. Japan has many such systems to process waste. Very little of such technologies are used in India.

Pyrolysis

Pyrolysis, another process of thermochemical conversion, is broadly a system which thermally decomposes carbonaceous materials. It has, unlike direct combustion, at least one zone in which the thermal decomposition takes place in the *absence* of oxygen. Pyrolysis can be based on either coal or biomass. All three phases of products are generated, solid char, a noncondensable gas and an organic liquid—oil (Table 5). Oxygen is only required in small and measured amounts to support combustion which releases just sufficient heat to initiate the endothermic (energy-consuming) pyrolysis process. Some examples of pyrolysis are the destructive distillation of wood and other agricultural products to produce methanol, charcoal and gas with a low to medium joule value.

Pyrolysis is usually carried out at near atmospheric pressures and temperatures of up to about 1100°C. Several factors, such as the final temperature, the type of biomass, the rate of heating, the proportion of oxygen present, and the equipment design all affect the yield and the product make up. Generally, charcoal yields are 30 to 40 per cent of the dry biomass feed. Gaseous product yields, based on the weight of the dry mass fed, range from 5 to 20 per cent depending on temperature. The main constituents of the gas are usually carbon monoxide, carbon dioxide, hydrogen and methane with higher proportions of hydrogen at elevated temperatures.

The liquid product, which is low in the troublesome sulphur, ash and nitrogen, can be as much as 25 weight per cent of the dry feed. It is composed of phenolic tar and an aqueous solution of pyroligneous liquor (mainly acetic acid, methanol and acetone). After removal or neutralisation of the acid, the liquid can be used as fuel. Tar can be separated from the aqueous phase by distillation or extraction. The charcoal produced is also low in sulphur and nitrogen, and much easier to store, transport and distribute than the biomass fedstock itself. Of course

Table 4. Biomass energy production and consumption in USA, Sweden, Brazil and India

	USA	Sweden	Brazil	India
Estimated population (million)	218	[illegible]	110	613
Surface area (million hectares)	1049	45	851	328
Population density (per hectare)	0.208	[illegible]	0.129	1.87
Rate of population increase	0.8	0.4	3.0	2.1
Cropland (million hectares)	192	3	[illegible]	162.8
Pasture (million hectares)	300	0.5	167	13
Forests (million hectares)	[illegible]	26	611	75
Other land (million hectares)	310	15	137	[illegible]
Per capita consumption of commercial energy (giga joules)	340.4	[illegible]	[illegible]	[illegible]
Per capita production of commercial energy (giga joules)	[illegible]	23.5	14.66	[illegible]
Per capita production of biomass energy (giga joules)	2.89	[illegible]	7.27	3.31

Biomass fuels: the Brazilian experience

IN Brazil, the conversion of fixed vegetable oils into diesel substitute has been under study for the last couple of years. A product called 'Prodiesel' substituting standard diesel oil is produced by catalytic esterification of triglycerides of soyabean, palm, babasu, cotton and palm seeds with both methanol and ethanol. The process is carried out at room temperature. The products consist of glycerol and the corresponding methyl and ethyl esters of the triglycerides. A composition of this product compared to standard diesel is given below.

It is reported that under identical conditions of engine performance, 10 per cent less of prodiesel is required than standard diesel. It is also reported that for 3 tonnes of oil seeds about 1 tonne of oil and 2 tonnes of cake are obtained. This amount of oil provides nearly 120 kg of glycerol and 1,200 litres of methyl esters. In the case of babasu fruit, the glycerol recovered is about 150 kg. A pilot plant of 1 kilo litre per day of prodiesel is in operation. The present import cost of diesel in Brazil is US $38 per barrel. When the import of crude would cost US $43 for a barrel, the production of prodiesel by this process will be economical. The key consideration of this process lies in the fact that glycerol compensates for the cost of product and at present it is sold at the same price as that of diesel.

If the cost of energy continues to rise faster than agricultural commodities, the potential competition for land between food, export and energy crops will be heightened as economic forces increasingly draw agricultural resources into energy production. Whether or not to produce energy from biomass will often require difficult choices which cannot be resolved using strict economic criteria. This is particularly true when such efforts affect the income of a large number of poor people. The solution lies in bringing arid and semi-arid lands into production in countries with such resources. In others, possible ways of reducing competition between cropping and production of food include: (i) increasing yields per hectare of traditional energy crops with cloning techniques and selecting species which are compatible to the soil, (ii) planting fast-growing energy crops such as sweet sorghum, and (iii) producing raw materials on land that is marginal for agriculture. Forest products could become important sources of ethanol (and methanol) if cellulose conversion technology can be improved and demonstrated. The area of marginal land under timber greatly exceeds the land available for sustained agricultural biomass production.

T.K.G.
V.S.B.

	Prodiesel (methyl ester)	Standard diesel
Energy/kg	43.75 MJ (mega joules)	47 MJ
Viscosity (relative units)	40	38
Specific gravity at 20°C	0.877	0.829
Cetane index	> 60	48
Sulphur	< 0.10%	1.3%
Solid discharge in emission (relative units)	0.7	1.0
Corrosivity MB 287 at 50°C	0	2.0

the energy value of the char is lower than that of the biomass and the gas is also of low to medium joule value.

Gasification

In gasification, another process of thermochemical conversion, organic matter is thermally decomposed with the help of an auxiliary gas such as air, oxygen and hydrogen to yield only gaseous products. The industrial generation of producer gas from sub-bituminous or anthracite coal is now more than a century old. Char and tar are converted at high temperatures into gaseous products. A lot of heat is needed and some air is introduced to cause partial combustion *in situ*. Char is very active and may be rendered into gaseous products by reacting with steam to give carbon monoxide and hydrogen.

Tar may also be dissociated in the same way. Enough steam is available in the system because of the initial moisture content and the released volatile gases. The reaction is induced by the steam to provide heat. Heat again can be produced by partial combustion of the gases in the presence of oxygen or air. Other reactions, such as the reduction of carbon dioxide to the monoxide occur. At this point no more solid or liquid remains, except mineral ashes, and, because of the prevailing high temperature, the resultant gases are driven off.

The heating value of the gases depends on the process conditions, the more the air introduced to give heat by partial combustion of the gases, the higher the proportion of the non-combustible gases and nitrogen coming from the air. About 14 to 16.7 giga joules per Nm³ can be obtained from a tonne of charcoal. A German firm (Imbert GmBH) has even developed a range of gas electric generators having 10 to 10,000 kVA capacities for gasification units for use in road vehicles and tractors. The gasifiers are highly efficient and eliminate tar and dust problems. One kilolitre of petrol and 2 kilolitres of diesel can thus be replaced by 2.5 tonnes and 3 to 3.5 tonnes of dry wood, respectively.

The conversion of dry organic residue to the cold, clean gas is 65 to 75 per cent efficient. The generation of electricity with an alternator and dual fuel engine is about 35 per cent efficient, giving a combined efficiency of nearly 25 per cent, compared to the 30 to 35 per cent obtained when electricity is produced from steam generated directly by biomass.

Liquefaction

Another technique that uses high temperatures to convert biomass is liquefaction. It can be both a direct and indirect process of thermochemical conversion. The former is usually catalytic, the feed being first converted into a gaseous intermediate from which liquid fuels are then synthesised. In one of the direct liquefaction processes, the biomass slurry containing the catalyst is fed to a high pressure (but not more than 280 kg per sq cm) and medium temperature (340°C) reactor where liquefaction reactions take place in a reducing gas atmosphere (with carbon monoxide and/or hydrogen also being fed to the reactor). A series of complex reactions occur simultaneously—pyrolysis, gasification and volatilisation. Hydrogasification by pyrolysis in the presence of hydrogen produces mainly methane and water. The gas, containing the combustibles, is removed and can be used as a heat source to pre-dry the wood feedstock. The liquid-solid mixture is then separated by distillation. The bottoms containing residual solids can be recycled together with a portion of the oil which is not removed as product. After the oil product is separated, vacuum distillation would allow a product as desired. The product composition will, of course, depend on the biomass feed.

In the indirect liquefaction process, there are two stages. In the first, the biomass is gasified to an intermediate species which in the second is converted to methanol, gasoline or polymerised liquid hydrocarbons. The intermediate mixture could be synthesis gas (carbon monoxide and hydrogen), light olefins (ethylene and propylene), etc. Methanol synthesis has been in wide commercial production for many years. Most methanol production today is based on natural gas as the feed source. This generally requires a higher hydrogen to carbon monoxide ratio than a biomass gasification unit.

Only methanol is being considered as a prospective alcohol to be derived from biomass by thermochemical means. At present, methanol from wood would be more expensive than that from coal, partly due to the smaller scale of biomass units. Nonetheless, there are opportunities to decrease the costs. Clustering the gasification units near biomass sources and transferring the gas to a central methanol unit could greatly reduce cost. The Mobil Corporation has also developed a process for converting methanol and other aggregates into high octane gasoline:

$$n(CH_3OH) \xrightarrow[\text{catalyst}]{} (-CH_2-)_n + nH_2O$$

With methanol feedstock a zeolite catalyst allows a yield of about 85 per cent of hydrocarbons (gasoline) containing virtually no component heavier than C_{10}.

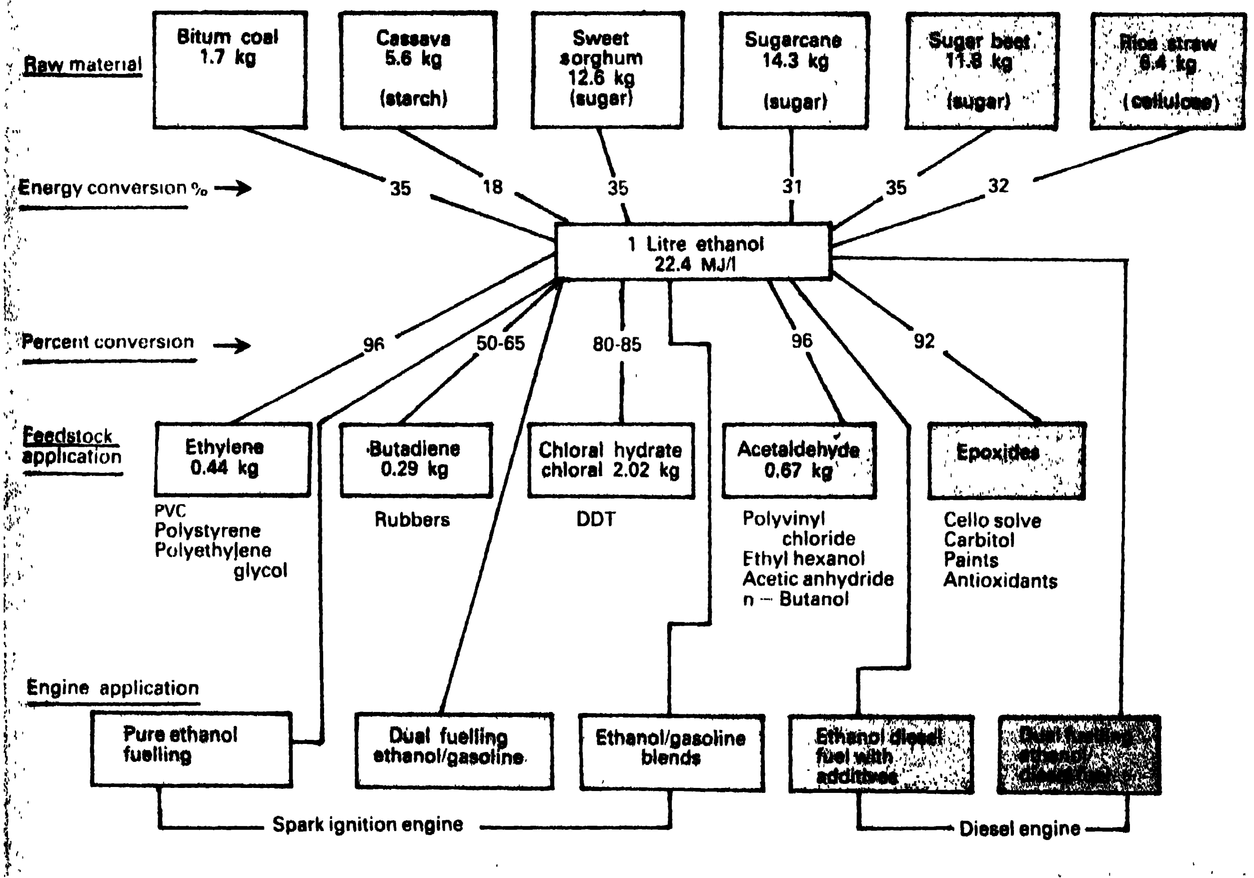
Biological conversion

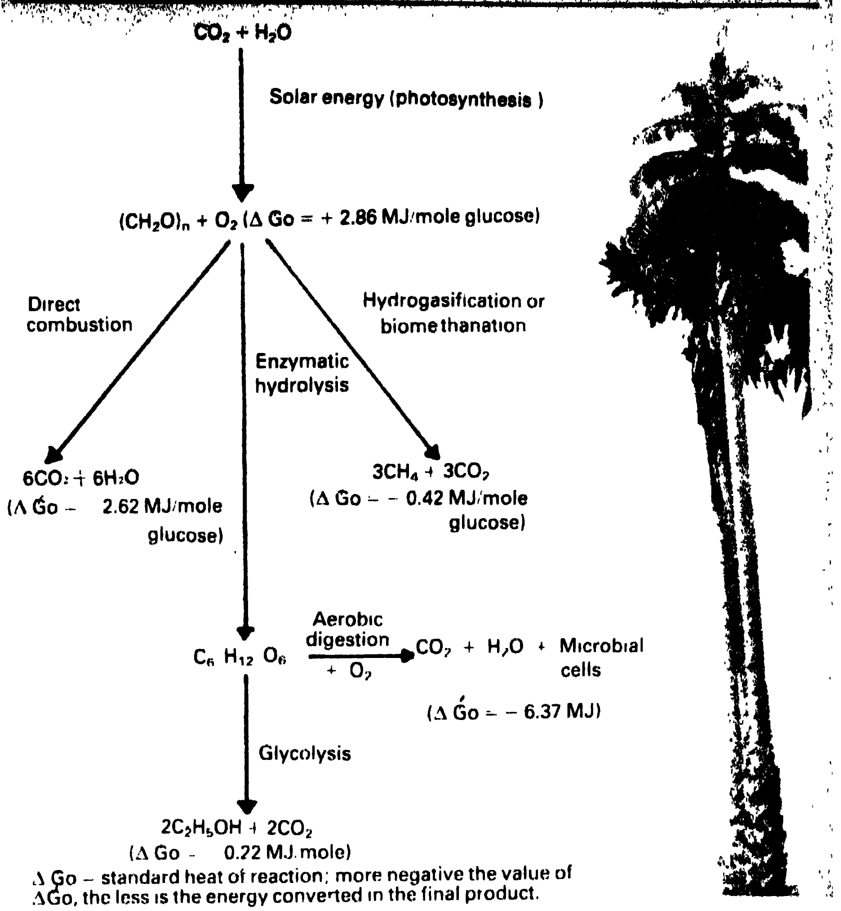
In contrast to thermochemical conversion processes, biological conversion processes are less energy-intensive, and take place at near atmospheric pressure at low temperatures (30 to 80°C). Biological conversion entails an energy-yielding enzymatic breakdown of biomass by selected species of microorganisms. The product can be gaseous and liquid fuels, food, animal feed, fertilisers and other chemicals.

Biomethanation

Biomethanation is an important biological conversion process yielding methane. It converts biomass in the absence of oxygen (by anaerobic digestion) to methane, popularly known as biogas, leaving a stabilised residue which makes an excellent organic manure. Traditionally in use for about a century, biomethanation is a very complex process which only recently is beginning to be understood. Basically anaerobic digestion consists of three phases: the enzymatic hydrolysis of biomass, organic acid formation, and methane generation. The total process requires a symbiosis of acid-forming and methane-forming microorganisms. The reactions of the two groups must

Fig. 3 Sources for ethanol production and routes for ethanol application




$CO_2 + H_2O$
Solar energy (photosynthesis)
$(CH_2O)_n + O_2$ (Δ Go = + 2.86 MJ/mole glucose)
Direct combustion
Enzymatic hydrolysis
Hydrogasification or biomethanation
$6CO_2 + 6H_2O$
(Δ Go – 2.62 MJ/mole glucose)
$3CH_4 + 3CO_2$
(Δ Go – – 0.42 MJ/mole glucose)
$C_6H_{12}O_6$
Aerobic digestion
$+ O_2$
$CO_2 + H_2O$ + Microbial cells
(Δ Go – – 6.37 MJ)
Glycolysis
$2C_2H_5OH + 2CO_2$
(Δ Go – 0.22 MJ/mole)

Δ Go – standard heat of reaction; more negative the value of ΔGo, the less is the energy converted in the final product.

Fig. 4 Energy output of photosynthetic biomass $(CH_2O)_n$ through various conversion processes

occur simultaneously; if these become unbalanced, the digestion process fails.

Methane production here is further influenced by three main factors—the nutrient components of the biomass substrate, the temperature and the pH. Carbon and nitrogen are essential for bacterial metabolism, so the suitability of the materials for methane production is based on their carbon/nitrogen ratio, which should be around 30 for optimum production.

There are two types of methane-forming bacteria, requiring different temperatures for optimum growth. The mesophilic organisms grow best around 35°C, while the thermophilic organisms find an optimum temperature around 55°C. Methane production decreases rather drastically as the temperature drops below optimum level so that temperature control is a must for good yield. As a thumb rule, methane production drops by 50 per cent for every 11°C decrease in temperature. A pH range of 6.7 to 7.6 is normally adequate.

Theoretically, in biogas plants, the fermentation of cellulose (the chief constituent of plant tissue., should give off equal amounts of methane and carbon dioxide, but actually, part of the carbon dioxide produced remains fixed on organic or mineral bases or remains dissolved in the water. Hence, biogas produced from farm residues consists of 55 to 65 per cent methane and 35 to 45 per cent carbon dioxide along with 0.3 per cent nitrogen, up to 1 per cent hydrogen, up to 1 per cent oxygen and traces of hydrogen sulphide. The biogas produced in a well functioning digester may have a heat value of 22.92 mega joules per cubic metre (compare the value for natural gas-39.58 mega joules per cubic metre). The energy value of the biogas can be increased by removing carbon dioxide by passing the gas through water. The gas may be used to provide heat in stoves or space heaters or for work in internal combustion engines.

If biogas is to be used in engines, hydrogen sulphide, the most corrosive component present in biogas of any origin, must normally be removed by the sponge iron process. The use of biogas as a diesel substitute has been successful by mixing 85 per cent biogas with 15 per cent diesel in engines to run tractors and other agricultural implements; this system has become popular among farmers.

When cowdung is used in biogas plants, an output of 0.063 cubic metre of biogas per kg of cowdung digested is possible. This is equivalent to 120 cubic metres of methane per tonne of volatile solids digested. Better outputs are reported from specially grown plants like water hyacinth. However, for practical reasons the methane yields are normally within 100 to 140 cubic metres per tonne of volatile solids digested—an efficiency of about 20 to 25 per cent.

Besides animal dung, current research efforts are also being concentrated on other biomass materials such as rice husk, straws, aquatic plants, etc, either alone or in mixtures. Digested biomass, an excellent manure and a good soil conditioner, contains 2 per cent nitrogen, 1 per cent phosphorus, 0.7 per cent potash and 50 to 70 per cent of organic humus.

Digestion of mixed residues (gobar, water hyacinth, algae, etc) gives greater overall efficiency, both in terms of energy recovery as well as the fertiliser value of the digested residue. A mixed residue resulted in a 2.3-fold increase in methane production as compared to cowdung alone. The separation of acidogenic and methanogenic phases and the application of multireactor system have been demonstrated to provide even greater overall efficiency. A methane yield of 230 cubic metres per tonne of volatile solids digested has been achieved in the latter system as compared to 159 cubic metres per tonne of volatile solids digested mostly reported (Table 6).

Ethanol fermentation

Besides biomethanation, the free sugars present in many crops like sugar cane, sugar beet, grapes and mahua can be transformed into ethanol by fermentation with the help of yeasts, for example, *Saccharomyces cerevisiae* and bacteria, for example, *Zymomonas mobilis*. This is a well established route of bioconversion. Starchy materials like potato, cassava, corn maize, barley, sweet sorghum, etc can also be transformed into ethanol through acid or acid-enzyme action, or a two-step enzymatic action of α-amylase and amyloglucosidase which is the most common practice.

Agricultural residues having low sugar or starch contents are principally composed of three organic constituents: 30 to 45 per cent cellulose, 20 to 40 per cent hemicellulose and 20 to 30 per cent lignin. The cellulose and hemicellulose components

Table 5. Feasible biomass conversion technologies

Thermochemical		
Combustion	CO_2, water, ash, heat, steam, electricity	Well established
Pyrolysis	Char, oil, gas	Smallscale
Gasification	(CO, C_2H_4, H_2)	Established
Gasification + catalytic synthesis	Methanol, hydrocarbons	Largescale under development
Biological		
Yeast fermentation	Ethanol + CO_2	Well established
Anaerobic digestion	Methane + CO_2	Established

can be converted into sugars by either acid or enzymatic hydrolysis. The enzymes, such as exoglucanase, endoglucanase, β- glucosidase and xylanases, derived principally from fungi, hydrolyse cellulose and hemicellulose to principally glucose and xylose sugars. Some other bacteria are able to convert cellulose directly into ethanol, though yields are very low.

Over the last few years considerable advances have taken place in the bioconversion of cellulosic residues into ethanol and other chemicals. Ethanol is an important feedstock for the manufacture of a large number of chemical derivatives, polymers and solvents, etc. Ethanol gasoline blends (20 per cent ethanol and 80 per cent gasoline), popularly known as gasohol, are currently being used in Brazil and the USA in transport vehicles with a view to saving gasoline (see SCIENCE TODAY, September 1980, p. 41). Ethanol is also being used in some places as a total replacement for gasoline in motor cars without much change in the power output. Some of the potential uses of ethanol and other degradation products of the lignocellulosic residues are shown in Fig. 3.

When we have to set up a large energy conversion process (thermochemical or biological) to obtain fuel or heat from biomass residues we will have to take into account a number of critical factors; the nature and quality of energy needs, the availability of organic residues to feed the plant, and the size of conversion plant. Above all, we will have to consider conversion efficiency. If the initial moisture content of biomass is high, an increasing part of the energy in the dry (thermochemical) processes is used to remove water. The available dry processes are, therefore, not appropriate if the initial moisture content exceeds 50 to 60 per cent. In such a case only about half of the calorific content is recovered. For materials containing 70 to 90 per cent moisture, only the wet biological processes are practical.

Microbial production of hydrogen fuel

Hydrogen gas is another ideal fuel, an alternative energy source and a highly efficient energy carrier. The heating value of hydrogen gas per unit volume is less than that for other gaseous fuels—for example, it is only one-third that of methane; however, the heat content per unit *mass* of liquid hydrogen is about 2.75 times greater than that of hydrogen — a fuel worth considering.

Hydrogen has a great potential for use as a primary or secondary energy source, for electrical storage and generation with fuel cells, and for chemical synthesis. As a fuel, hydrogen has a wider range of explosive concentrations in air than natural gas. However, the lower explosive limit is nearly the same for both the gases.

Both photosynthetic and non-photosynthetic bacteria and algae produce large amounts of hydrogen under anaerobic conditions. Some of the organisms involved in hydrogen production are: *E.coli, Citrobacter intermedices, Clostridium butyricum, Sirulina maxima, Bacillus macerans*, etc. There are basically four processes of hydrogen production from non-fossil primary energy sources. The first three are water electrolysis, thermochemical and radiolytic processes. The fourth process is biological and based on microbial synthesis.

Research on biocatalytic production of hydrogen gas has been going on for a couple of decades, but a major bottleneck in large scale production has been a low yield of hydrogen. Two basic inputs for hydrogen production are sunlight and an electron donor. There are two main problems which must be sorted out to render hydrogen production practicable; these are, low solar energy conversion efficiency (the amount of hydrogen per unit of solar energy) and an adequately inexpensive electron donor and multiple utilisation of the by-products of the hydrogen photoproduction system.

Social and environmental considerations

Biomass energy systems can greatly improve the quality of life in the rural areas. The growth, harvesting and transportation of biomass provide opportunity for employment, and biomass energy cropping will also generate additional income for rural areas retarding migration to the cities.

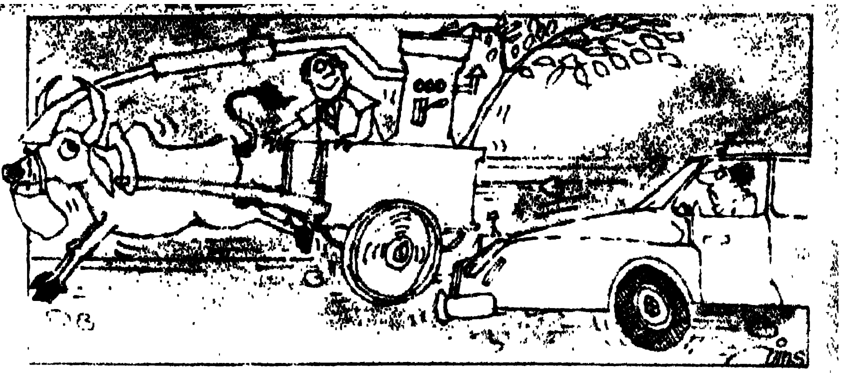
Only marginal lands, arid and semi-arid regions appear to be candidates for energy crops. If too much residue is removed from soil in use, erosion and depletion of soil nutrients take place. This is particularly true if thermochemical conversions based on agro and forest residues are practised on an extensive scale. Since production of biomass is a biological phenomenon, return of most of the biodegradable constituents of biomass to the soil is a necessary link in the chain and can only be ensured to a larger extent by the bioconversion process like methane production. Based on studies available, the potential environmental impacts of biomass-based energy production seem to be small as compared with those associated with the use of most other energy forms.

Collection of biomass can be facilitated by locating the processing plants near the collection sites. If the plants have to be decentralised, then their sizes should be based on resources available locally. Several region-based case studies on the energy, food, quality of life and health environment should be undertaken to

Table 6. Comparison between different modes of digestion (15 days) (BERC data)

* Single substrate – dung
** Multiple substrate – dung + water hyacinth + algae

provide a further insight into specific problems to be encountered in selecting a site. One of these important issues is now being handled in India by an organisation called the Centre for Regional Ecological and Sciences Studies for Development Alternatives. It covers Orissa, West Bengal and Bihar and is chaired by P. N. Haksar.



National efforts on biomass resource utilisation

Because of a lack of serious concern about biomass so far, some people tend to equate biomass energy systems with agriculture and forestry practices. There are, however, some basic distinctions between biomass and the traditional agriculture and forestry. Biomass has a much wider variety of availability and much wider options for the conversion of these species into portable, storable and readily available forms of energy. Indeed, the analysis of any biomass conversion process must take into account the logistics of feedstock supply, feasibility of the technology and the likely competition that such a use may face from other alternative uses. In the case of a chemical conversion system some of these issues are trivial. Production of bulk chemicals based on biomass is another area in which little or no attention has been given. Above all, the country does not have any declared science policy in the biomass energy systems. Only a true understanding of an interdisciplinary knowledge of photosynthetic productivity, ecology, biotechnology, global energy systems and social issues will help establish a national biomass energy policy in relation to other forms of energy for the country.

According to the National Paper of the Government of India submitted to the United Nations Conference on New and Renewable Sources of Energy (Nairobi, 1981), two centres for research on the production of biomass are also being established, one at the National Botanical Research Institute, Lucknow and the other at the Madurai Kamaraj University, Madurai. The technology of biomass conversion, research and development programmes covering extensive areas and routes based on agricultural residues like bagasse, rice husk, rice straw,etc and animal droppings as substrates are being actively pursued at BERC, IIT, Delhi for more than a decade now. Major breakthroughs achieved by this group include rapid ethanol production, novel bioreactor development, maximisation of recovery of methane and lower fatty acids from digestion of dung and residues in various modes (Table 6), rapid conversion of starch into sugars, efficient conversion of cellulose into acetone/butanol, production of sweeteners from cellulosic residues and bioconversion of rice straw into improved fodder. Other centres working on bioconversion include: Murugappa Chettiar Research Centre, Madras; Khadi and Village Industries Commission; G. B. Pant University of Agriculture & Technology, Pantnagar; National Dairy Research Institute, Karnal and Bangalore; Bhartiya Agro-Industries Foundation, Pune and National Chemical Laboratory, Pune.

Despite the unlimited potential that is attached to the lignocellulosic conversion into ethanol, only a few centres around the world are engaged in research and development studies in this important area In the area of thermochemical conversion systems, better design of pyrolysis and gas producer plants are urgently called for. BERC, IIT, Delhi, is one of these centres and some major breakthroughs have already been made in this area.

BERC. has carried out detailed studies on the enzymatic production of ethanol from cellulose hydrolysate in batch and continuous systems employing free cells, recycled cells and also immobilised cells. The centre was the first to publish data on ethanol production from enzymatically hydrolysed cellulose. BERC has also developed a yeast strain which is tolerant to high concentrations of glucose and ethanol. A

Table 7. Recently updated conversion data on ethanol production based on various feedstocks

Process	Feedstock/organism	Sugar conc. (%)	Ethanol conc. (%)	Productivity g/l/hr	Source
Batch	Molasses/*S. cerevisiae*	12-14	6.5-7.0	1.3	Conventional
Batch with cell recycle	Molasses/*S. cerevisiae*	13	10	4.8	Alfa Laval
Batch with cell recycle	Bagasse hydrolysate/ *S. cerevisiae*	25	12	6.9	Biochemical Engineering Research Centre, (BERC), IIT, Delhi
Continuous with cell recycle	Bagasse hydrolysate/ *S. cerevisiae*	15	8	32.0	BERC, IIT, Delhi
-do-	Glucose/*S. cerevisiae*	10	5.3	29.0	Lawrence Berkeley Lab, University of California, USA
Vacuum fermentation	Glucose/*S. cerevisiae*	33.4	16	40.0	-do-
Immobilised cell reactor	Molasses/*S. cerevisiae*	15	9.8	28.6	BERC, IIT, Delhi
Immobilised cells on cal. alginate	Glucose/*Z. mobilis*	15	6.4—9.0	44	University of NSW, Australia
Immobilised cells on borosilicate glass	Glucose/*Z. mobilis*	5	2.5	71	Oak Ridge National Lab, USA
Immobilised cells on carragenan	Glucose/ *S.carlsbergensis*	10	6.4	50	Tanabe Seiyaku Co Ltd, Japan

novel technique of fixing yeast cells in an inert support and using it in the continuous production of ethanol at various dilution rates has also been developed. It has been applied successfully to both bagasse hydrolysate and cane molasses. Other studies include the use of thermotolerant yeast and bacterial species. The cell recycle system has been run with 5, 30 and 300 litre reactors and is ready to be scaled up; this technique has a steady operational stability of nearly 400 hours, while the immobilised system has been run for more than 75 days without any loss of activity (see Table 7).

The pace at which India can exploit her renewable energy potential will be determined in a good measure, as mentioned at the beginning of the article, by the country's ability to create and strengthen the necessary facilities, and motivate group activities to suit local conditions, in particular for rural development. The expertise needed to evaluate and exploit these resources exists in India. There are, however, large gaps which still need to be identified but these are not necessarily of the same order of magnitude as in the industrialised countries. To fill these gaps, proper attention needs to be given to strengthening national research programmes, coordinating new activities and establishing demonstration plants to study the feasibility of specific biomass energy technologies.

Table 8 Potential uses of products derived from lignocellulosic residues

Products	Uses
Glucose	Energy (alcohol, ATP), protein, chemicals, sweetener
Xylose	Ethanol, xylitol (sweetener), SCP, antidiabetic agent
Ethanol	Chemicals, solvents, beverages, biological energy (ATP), petrochemicals synthesis (via ethylene), gasoline diluent and octane enhancer, food and feed
Furfural and 2,3-butanediol	Chemicals and solvents (such as methyl ethyl ketone)
Lignin degradation products: vanillin, dimethylsulphide, dimethylsulphoxide, methyl mercaptan, ferulic acid, etc.	Chemicals and solvents
Butanol–lignin slurry	Furnace and diesel fuel
Acetone–butanol	Solvent and explosives
Lignin sulphonates	Additives in stabilisers, grinding aids, etc.

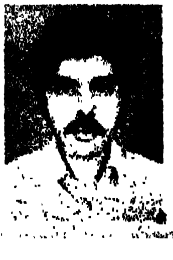
To conclude, the research and development and extension work should aim at more efficient utilisation of current biomass resources, extension of the resource base through introduction of new feedstocks or conversion technologies and extensive use of science and technology in the production and conversion of biomass. The following areas of biomass resource-based energy programme are specifically suggested for detailed investigation:

1. Adoption of massive afforestation and energy plantation projects in arid and semi-arid regions.
2. Extension of biomethanation technology based on domestic wastes (night soil in particular), manures, agricultural residues and animal droppings throughout the country. This will also ensure improved sanitation for our rural area.
3. Bioconversion of lignocellulosic biomass to ethanol in an integrated system incorporating the production of biogas, biofertiliser and sugars for industrial applications.
4. Conversion of non-edible oils to diesel substitutes and large scale trials of such a possibility in the country.
5. Large scale and organised production of aquatic biomass species like algae, water hyacinth, kelp, etc to be incorporated in the nation's rural development plans and such alternatives integrated into an energy-food-ecology system.
6. Thermochemical and chemical conversion of biomass in small and large scale gaseous and liquid fuels (especially methanol) and bulk chemicals production system.

Table 9 Major symposia–documents in the field of biomass energy in India since 1976

Symposia–documents	Reference
Agricultural residues and their utilisation in some countries of South and South-East Asia (UNEP/FAO seminar) (1976)	Regional Research Lab, Hyderabad
Utilisation and recycling of agricultural and animal wastes–by-products (1971)	Deptt of Science and Tech, New Delhi
International course-cum-symposium on bioconversion of cellulosic substances into energy, chemicals and microbial [illegible] (1977)	BERC, IIT, Delhi
Microbial technology in the provision of energy and chemicals from renewable resources (submitted to IUPAC) (1978)	BERC, IIT, Delhi
Report of the working group on energy policy (1979)	Planning Commission, New Delhi
Residue utilisation: Management of agricultural and industrial residues of [illegible] crops (1979)	Division of Soil Science and Agri Chemistry, IARI, New Delhi
[illegible] International course-cum-symposium on bioconversion and biochemical engineering (1980)	BERC, IIT, Delhi
[illegible] production of ethanol from [illegible] molasses and lignocellulosics in India (1980)	-do-

Prof. Ghose is Senior Professor and Head, Biochemical Engineering Research Centre, at the Indian Institute of Technology, Delhi. He obtained his Ph D from the Swiss Federal Institute of Technology, Zurich, as a Fellow of the Volkart Foundation. Prof. Ghose was also visiting Professor at the Monash University, Australia, the Swiss Federal Institute of Technology, Zurich, the Melbourne University, Australia and the Rutgers University, NJ, USA. Prof. Ghose has made pioneering contributions in the development of a number of biochemical engineering processes, in particular on ethanol, methane and high fructose syrup from carbohydrate and cellulosic residues, including the development of novel reactors like the membrane reactor and the immobilised cell reactor. He is a member of the UN Expert Panel on Biomass Engineering and a Titular Member of the Biotechnology Commission of IUPAC.



Dr Bisaria is Assistant Professor in the Biochemical Engineering Research Centre, at IIT, Delhi, from where he obtained his Ph D. He specialises in microbial biochemistry and separation processes.

ROUND-UP OF RESEARCH

Gene transfer in plants

IN PLANT breeding, it is often desirable to improve one or two specific characters of an otherwise high-yielding, well-adapted cultivated species of a plant (the cultivar). For instance, the high-yielding wheat cultivar, Kalyansona, was extremely popular in the country's northern wheat belt till it became susceptible to leaf-rust disease a few years back. It would be ideal therefore to incorporate into this cultivar genes which would make it resistant to rust, but retaining all its other good qualities. One way to accomplish this has been to cross the cultivar with one that is resistant, followed by repeated back-crossing of the resistant progeny with the original cultivar. But this is a lengthy procedure, taking many years, and some of the desirable attributes are also lost in the process due to hybridisation.

If the required character is not available within the species, the breeders look for it in related wild species. They then try to transfer it to the cultivated species. But such a transfer of genes from an alien (distantly related) species is even more difficult; they also often carry the undesirable characters of the wild species. Kamal Kant Pandey, a well-known plant geneticist of Indian origin now working in New Zealand for many years, was the first to report transfer of specific genes in *Nicotiana forgetiana*, a wild tobacco species, through pollen "killed" by gamma irradiation of 100 kilorads. Later, he demonstrated similar gene transfers through irradiated pollen in several other species of tobacco. But these results and the probable mechanisms suggested by Pandey were viewed with skepticism.

Recently, J.L. Jinks and colleagues have reported results similar to those of Pandey (*Nature* **291** 586). In their experiments, a *Nicotiana rustica* (a related species of tobacco) strain V27, having three recessive marker genes—yellow plant colour, mop inflorescence and lack of black anthocyanin pigment in ovary—were pollinated with normal and gamma-irradiated pollen, from strain V12. The pollen parent V12 had the dominant alleles for the three marker genes: green plant colour, non-mop inflorescence and black anthocyanin pigment in ovary.

The two strains differed in other quantitative characters also. The first-generation plants (M1) obtained after using irradiated pollen were more variable than the uniform hybrids (F1) from unirradiated pollen. In the second generation, obtained after self-pollination of M1 plants, there were six (out of 87) plants which showed the maternal characters for two major genes (yellow plant colour and mop inflorescence) and, in addition, had the black anthocyanin pigment of the pollen parent. These six plants, though very close to the maternal parent for such quantitative characters as plant height, did show slight deviation, suggesting that, besides the major genes for ovary pigment, some minor genes influencing the plant height had also been transferred.

This is an elegant demonstration of gene transfer through irradiated pollen. The authors have refrained from discussing the possible mechanism involved. Nevertheless, Roy Davies in his write-up in the same issue of *Nature* (p 531) has made speculations, on the lines earlier suggested by Pandey, that the mechanism of gene transfer essentially involves: (1) fragmentation of pollen chromosomes, (2) transfer of these fragments to the egg cell, (3) parthenogenetic development of egg cell (reproduction of unfertilised ovum) induced by pollen tubes from irradiated pollen, (4) diploidisation of egg cell or early embryo, and (5) attachment or integration of paternal chromosome fragments (or DNA) to maternal chromosomes in the egg cell during chromosome duplication.

This technique could be a powerful new tool for plant breeders only if similar gene transfers can be made from distantly related species that do not produce sexual hybrids This approach may, perhaps, be easier and better than parasexual hybridisation involving fusion of protoplasts (cells devoid of their cell wall) from distant species. However, it is too early to assess its utility unless similar results are repeated in other plants also. Crucial to the application of this technique is the induction of matromorphs (parthenogenetic, diploid plants carrying only the maternal genome).

A large number of plant geneticists in India make use of ionising radiations to induce genetic variability in cultivated plants. It would be worthwhile if some of them could explore this new tool of pollen irradiation to bring about specific gene transfers in plants of economic importance. Of course, the right choice of material and markers would be essential to get the correct answers.

C. R. BHATIA

Dr. Bhatia is with the Mutation Breeding Section of the Biology and Agriculture Division, Bhabha Atomic Research Centre, Bombay.

Malaria vaccine protects offspring

MALARIA, one of the most widespread parasitic diseases, is on the rise again. The *Anopheles* mosquito which acts as a carrier of the parasite ***Plasmodium*** has drastically changed its behaviour and developed resistance to malaria drugs. Hence, the thrust is now to the development of an effective vaccine against malaria. But problems are many. For instance, the parasite undergoes several stages before it completes its life-cycle in the host. Hence the antibodies effective for one stage may not be good at another. Also, there is the problem of availability of enough sporozoite material of one particular stage, and short duration of the protective effect.

As early as 1937 it was demonstrated that blood serum obtained from an immunised individual and carrying the specific antibodies (immune serum) when passively transferred, protected the rhesus monkey from malaria caused by the ***Plasmodium knowlesi***. Since then, several observations showed the beneficial effect of passive transfer of resistance to different strains of malaria in appropriate hosts. In 1967, R. S. Nussenzwei reported total immunity against the stage-specific infection with *P. berghei* in rodents. This was achieved on immunisation with radiated sporozoites by intravenous route. Similar possibilities of active immunisation using this and other methods have been recorded in humans, monkeys and birds (SCIENCE TODAY, December 1980, p. 28). In all these studies, adult animals were used. The effectiveness of such a method in inducing immunity in children, who are most vulnerable to malaria infection, was yet to be assessed That such a resistance to malaria infection can be induced in infant animals has recently been reported again by Nussenzweig and colleagues, *Nature* **291** 331.

These investigators collected sporozoites of rat parasite *P. berghei* (ultimate development stage in the mosquito) and subjected them to gamma irradiation to remove their infective potential. These were then inoculated one to three times in each of the young mice (2 to 24 days old) and in adults (8 to 10 weeks old) by intramuscular route They then challenged the immunised animals along with appropriate controls with normal sporozoites by intravenous routes and watched

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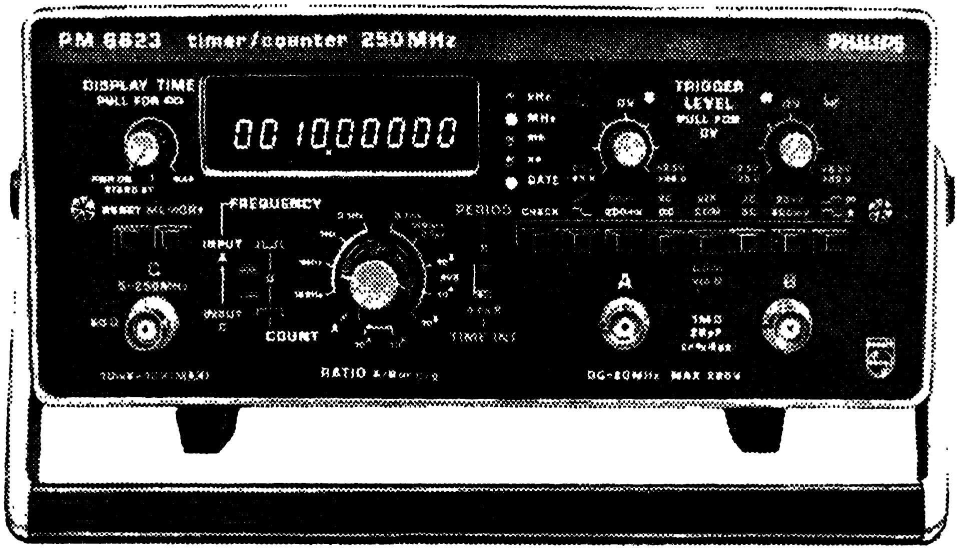

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for infection. The results showed that 80 to 93 per cent of the young immunised mice did not develop the infection while all the controls died of malaria. However, there was significantly lower protection (33.3 per cent) in immunised adults, possibly due to immunisation by intramuscular route, instead of the more effective intravenous route.

The other aspect taken up by the investigators was whether sporozoite-immunised mice could transfer protection to their offsprings. They found that pups (of 18 to 25 days age), born and nursed by immunised mothers, showed high degree of resistance (60 per cent) to challenging infection with normal infective sporozoites. However, at less than two weeks age the young ones showed a natural resistance to malaria infection, possibly because of their exclusive nourishment on milk diet. Incidentally, it is known that rich casein diet can induce resistance in rodents against malaria. The antibody levels against malaria in infant mice, which were low at birth, increased gradually with suckling time, suggesting their passive transfer through milk.

Electron micrograph of the malarial parasite

Also, the authors observed resistance to infection in pups born to non-immunised mothers when fed by immunised foster mothers. On the other hand, all offsprings of immune mice nursed from the first day onwards by non-immune mothers lost their antibody levels and became susceptible to normal sporozoite-induced infection.

Thus, these authors clearly demonstrated that, first, it is possible to induce resistance to malaria infection in infant mice by active immunisation and, second, that protective antibodies pass through colostrum (the first milk secreted by mammary glands) from mother to pups and confer protection to the young ones.

While the data yield valuable information on the modes of induction of resistance in infants to malaria, the practical application of such observations to man await solution of several problems which are encountered in the development of malaria vaccine. At any rate, it seems inconceivable to expect that passive immunisation could ever be the solution for malaria control.

D. SUBRAHMANYAM

Dr. Subrahmanyam is Director of a multinational industrial research centre in Bombay. His main research interests are in the field of immunology of communicable diseases such as malaria, filariasis and tuberculosis.

A tunable source of gamma rays

THE observation of positronium negative ion at the Bell Laboratories, USA, makes feasible a continuously variable energy source of gamma rays. Gamma ray sources available are usually naturally occurring or laboratory-produced radioactive nuclei. They emit gamma rays at certain fixed energy levels which are characteristic of the nuclei concerned. This possibility of having a variable energy gamma ray source may open up many new channels of experiments.

Positrons are positively charged particles of mass identical to that of electrons but of opposite charge. They may be called antiparticles of electrons: They were predicted by P.A.M. Dirac in 1932 and subsequently detected in cosmic rays. These particles are also emitted during the decay of certain radioactive nuclei. When a positron meets an electron, they ultimately annihilate each other, releasing gamma rays of energy equivalent to their added masses. In most such decays, two gamma rays, of energy 511 keV each, are released.

As a step towards the annihilation, the electron and the positron could orbit around each other forming a positronium atom (Ps). It is in many ways analogous to the proton of a hydrogen atom (H) being replaced by a positron. Drawing on this similarity we would expect a negative ion of positronium (Ps^-) to consist of two electrons and one positron. In fact, as early as 1957, J. A. Wheeler had predicted the binding energy of Ps^-, against breakup as Ps and a free electron, to be 0.3266 eV. The Ps^- was also predicted to have a short lifetime (about 5×10^{-10} sec) for decay into two gamma rays and an electron, this being the dominant mode of decay.

Allan P. Mills, Jr. of Bell Laboratories, USA (*Physical Review Letters*, **46**, p 717) used positrons from radioactive cobalt (^{58}Co) source and slowed down to an energy of about 1 to 2 eV with the help of copper and sulphur moderators. These positrons were then accelerated to about 400 eV and guided by a solenoidal magnetic field onto a 40 A thick carbon film, the whole assembly being in a vacuum of 10^{-9} Torr. The thickness of the carbon film was so chosen that the positrons emerged through the foil with very small energy (less 10 eV).

It was hoped that on passing through the carbon film, some of the positrons would acquire two electrons and form the Ps . Previous experiments had shown that in this process the Ps^- was usually formed. To detect the Ps^-, Mills placed a grid, biased positively, in front of the carbon film so that the Ps^- would be accelerated, whereas the positrons would be repelled and the neutral Ps would be unaffected. The annihilation of positrons in neutral Ps would give unshifted gamma rays. But as the positrons in Ps^- annihilate during motion, the gamma rays seen in the forward direction would be blue-shifted due to the Doppler effect, that is, their energy would be higher than the nominal value of 511 keV. A germanium detector placed in the forward direction measured the energy spectrum and a fraction of the gamma rays were found to have higher energy as expected. The energy shift is directly determined by the voltage difference between the grid and the carbon film, and thus can be varied at will. For example, a voltage difference of only 1 kilo volt produces an energy shift of about 19 keV from the unshifted value of 511 keV. Thus the annihilation of positronium negative ion in flight provides us with a tunable source of gamma rays with precisely known relative energy shift.

AMIT ROY

Dr. Roy is with the Nuclear Reactions Group at the Tata Institute of Fundamental Research, Bombay

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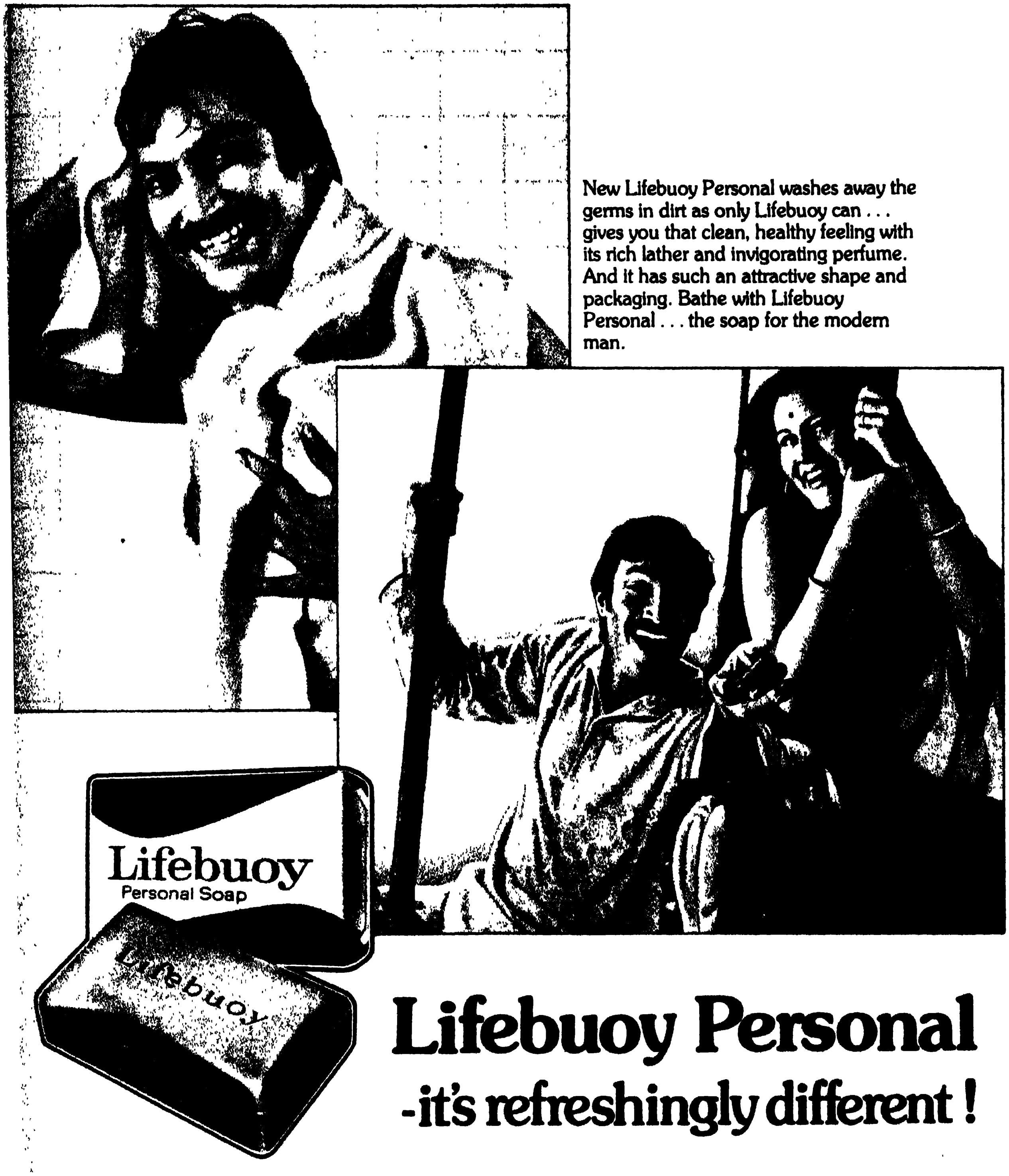

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THE METHOD OF SCIENCE: INDUCTION OR DEDUCTION?

R. R. Daniel

[illegible]

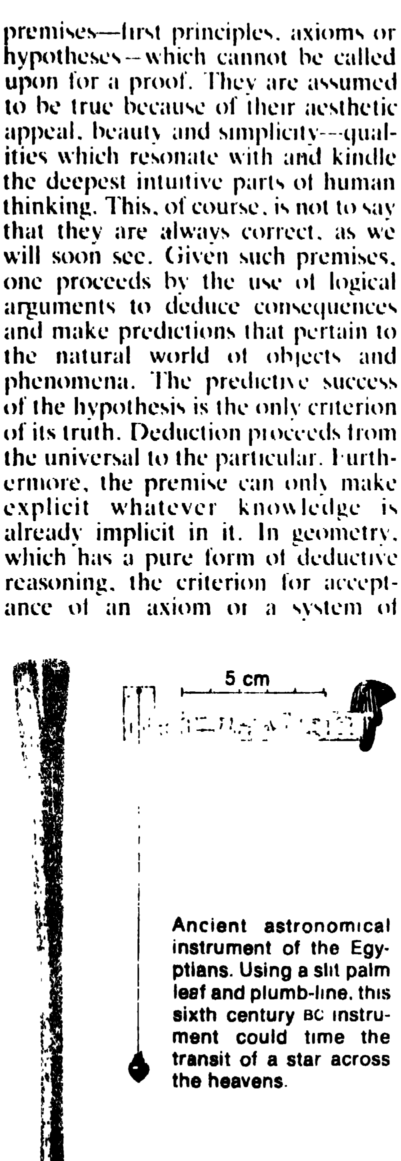
Philosphers refused to look at sunspots through Galileo's telescope because the Sun could not have spots on 'rationalistic', deductive grounds. But Einstein, by deductive methods, revolutionised science in a matter of ten years.

TWO of the most glorious epochs of the history of science are those of the Greek philosophy of the 6th to the 3rd century BC and, two thousand years later, of the European Renaissance from the 15th to the 17th century AD. Historians and philosophers of science attribute the two basic methods of scientific inquiry, the deductive and the inductive, to these two epochs—the deductive method to the Greek philosophy and the inductive to the Renaissance. While there is some truth in such a division, things are not as simple as this.

Even a partial historical review will make it clear that new knowledge is never acquired by pure deductive or inductive methods, but rather by an alloy of the two with contributions from both. Nor is there a fixed proportion between inductive and deductive methods. The varying fractions depend on diverse factors, including the socio-religious milieu and the individual genius of the scientist. The final outcome is a hierarchy of theories, the higher one subsuming the lower.

Many people today have a very simple notion, bordering on the vulgar, of the method of science and how it develops. This breeds a dogmatic arrogance in favour of one or the other of its pillars. This is especially true of inductive philosophies which some of their adherents consider to be self-correcting. Here I shall attempt to give some idea of the diversity and richness of scientific development. It would take more than a book to go into the subject and hence, for illustration, I shall confine myself to some of the episodes in the history of astronomy relating to motion and gravity.

In the pure deductive method, one, essentially begins with self evident premises—first principles, axioms or hypotheses—which cannot be called upon for a proof. They are assumed to be true because of their aesthetic appeal, beauty and simplicity—qualities which resonate with and kindle the deepest intuitive parts of human thinking. This, of course, is not to say that they are always correct, as we will soon see. Given such premises, one proceeds by the use of logical arguments to deduce consequences and make predictions that pertain to the natural world of objects and phenomena. The predictive success of the hypothesis is the only criterion of its truth. Deduction proceeds from the universal to the particular. Furthermore, the premise can only make explicit whatever knowledge is already implicit in it. In geometry, which has a pure form of deductive reasoning, the criterion for acceptance of an axiom or a system of axioms is merely that it should be free from contradictions—in other words, that the system should be consistent as a whole.



Ancient astronomical instrument of the Egyptians. Using a slit palm leaf and plumb-line, this sixth century BC instrument could time the transit of a star across the heavens.

Induction, on the other hand, means reasoning in support of a general proposition by consideration of particular cases. Aristotle called it "a passage from individuals to universals", while in the nineteenth century John Stuart Mills called it as "that operation of the mind by which we infer that what we know to be true in a particular case or cases will be true in all cases which resemble the former in certain assignable respects". Even the Greek period which is often considered to be synonymous with the peak of deductive genius, contains a considerable element of induction, and when scientific inquiry was attempted with deductive means, divorced from experimentation and verification, the consequences were injurious to the cause of science.

Pre-Socratic Greek science

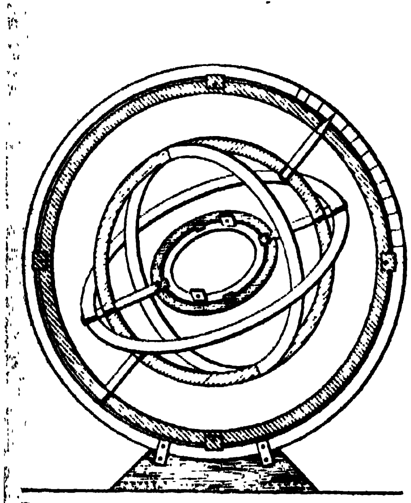
The pre-Socratic period starts in the Ionian colony of Miletus in Greece around 600 BC and ends with Democritus around 420 BC. Thales, the first of the Milesian philosophers and a great traveller, is thought to have brought to Ionia the knowledge of geometry from the Egyptians, of navigation by stars from the Phoenicians, and of astronomical tables from the Babylonians.

Thales, living in a Greece that was pagan, with its many gods and legends, did an audacious thing for his time. He stripped all the knowledge and the cosmogonies he brought to Ionia of their religious inheritance and respective myths. Instead of regarding the stars as gods—which they were before him, and remained long after him—Thales was the first Greek to treat them as natural objects. Ionian philosophy and its tradition, originating from Thales, were thus materialistic. This trend comes out sharply in Anaximander, also of Miletus, who thought fishes were a form of life that preceded land animals and that man had once been a fish, a view quite contrary to the stories of creation current amongst the Babylonians and others of his time.

Yet, Pythagoras, another stalwart of the Ionian period, originated the religious and deductive tradition of Greek thought on the nature of things. The Pythagorean community was a secret religious brotherhood held together by its practice of asceticism and the study of mathematics. It found in mathematics a key to the riddle of the universe and an instrument for the purification of the soul. Plutarch, a good Pythagorean, says of geometry, "It draws us away from the sensible and the perishable to the intelligible and the eternal." And Philalaus, another Pythagorean, says of numbers, "Consider the effects and nature of number according to the power that resides in the decade [the first ten natural numbers]. It is great, all-powerful, all sufficing, the first principle and the guide in the life of gods, heaven and men."

For the Pythagoreans, then, religion and mathematics were inseparable and their mathematical philosophy soon became a rival to the Ionian natural philosophy. They constructed matter out of numbers and a cosmos out of geometry. Naturally enough, the idea that heavenly bodies are divine led to the postulate that they are spheres—for what could be more perfect?—and have circular and uniform motion which, with no beginning or end, is eternal and so, perfect. It is also very interesting to note that in their universe not the Earth or the Sun, but fire was at the centre and the Earth, the Moon, the Sun and the fixed stars moved around it. Pythagorean geometry was given a sound and formal shape by Euclid about 200 years later.

Ionian science, however, came full circle with Democritus who lived around 420 BC. His atoms, the building blocks of his natural world, had bulk but were indivisible and impenetrable. His statement, "Nothing is created out of nothing", is a brilliant anticipation of the principle of conservation of matter. In some respects he is the culmination of the Ionian inquiry into the nature of the universe and the working of nature by unseen, but natural bodies.



Ptolemy's *Astrolabon*. This complicated instrument is only one of the many described by one of the greatest astronomers of antiquity. Even if he represented the geocentric view, Ptolemy was a great experimentalist, astronomer and geographer The instrument is not to be confused with the *Astrolabe*, a calculating instrument

The Athenian science

The Athenian school of philosophy, which later became dominant, drifted further and further away from the Ionian tradition. Its dominance is the source of the mistaken identification of Greek philosophy with the deductive method. Socrates, with whom the school begins, was essentially a moral philosopher who turned the attention away from physics and technology to ethics. What we know about him comes from the writing of Plato, his disciple. Socrates' influence discouraged research into nature and substituted a religious view which had come down from Pythagoras. He made no worthwhile contribution to science or its cause. Plato also followed the general trend of the Pythagorean philosophy and included a belief about the immortality of the individual soul in his philosophy. Plato considered astronomy, as well as acoustics, as an impious study. Though he, like Socrates, made no contribution to science, he advanced the study of logic more than any one else before him. Geometry, the deductive science par excellence, was central to his philosophy. On the door of his Academy was written, "you cannot enter here unless you know geometry".

Aristotle, in contrast to his mentors Socrates and Plato, was both a philosopher and a scientist. He did not let the twenty formative years he spent at the Academy of Plato dim his independent thinking about nature. When Plato died in 348 BC, Aristotle complained that the Academy was turning philosophy into mathematics and left for Ionia. He returned to Athens in 334 BC, and established his own school, the Lyceum. Aristotle tried to synthesise Platonic idealism with a commitment to the Ionian positive science, but the Platonic deductive method remained dominant. Aristotle continued to treat the heavenly bodies as spheres and their rotation as uniform circular motions—beautiful, elegant and aesthetically appealing concepts, but quite wrong. To these he added the geocentric nature of the universe as a first principle. He could then explain the apparently erratic motion of the planets as due to circular movements on eight spheres for Saturn and Jupiter, and many more for others. Yet we now know that these ideas, elaborated and systematised later by Ptolemy, became stumbling blocks for further progress for nearly 2000 years.

Pythagoras, mathematician and philosopher who originated the religious and mystic tradition in Greek philosophy

The history of Greek science also suggests that it was considerably influenced by the socio-economic and political milieu in which the Greeks lived. In Ionia a class of merchants and manufacturers held political power whose very strength was their command and control of techniques. This gave rise to a powerful inductive science and a boldness to do away with gods and myths. But, then, Pythagoras also lived during the Ionian period!

Plato and Aristotle lived in a society in which the slave system was

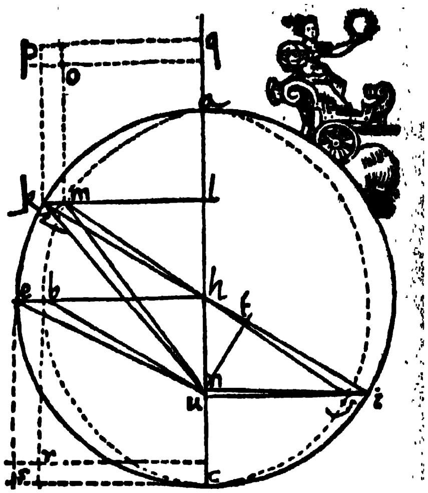
Nicholas Copernicus, the first to openly proclaim the heliocentric theory in face of the rigid geocentric orthodoxy of the church

firmly established. The social structure was well reflected in the philosophy of these giants too. In the Platonic republic, Plato's philosopher-aristocrats who constitute a minority of the people rule over the rest. Aristotle too believed in the master-slave society and its extension to the role of philosophy and science. All this suggests that in real life there is more to the methods followed by scientists than pure rational thinking. Science indeed is a very human enterprise.

Historically, Greek philosophy is thought to be the beginning of science, but after this beginning nothing even remotely comparable to the Greek explosion of knowledge occurred for the next 1500 years in Europe. A simplistic view can hardly explain this huge gap. It was in the later Middle Ages that events exerted a decisive influence on the progress of science (and of religion) in Europe: the Crusades, which gripped Europe and the Middle East were just about over; the whole of Aristotle's writings were recovered; the first universities came into being at Bologna, Paris and Oxford and the cathedral and monastic schools of the catholic church flourished and reached a high point. The European Renaissance and Reformation were about to begin.

Science during the Renaissance

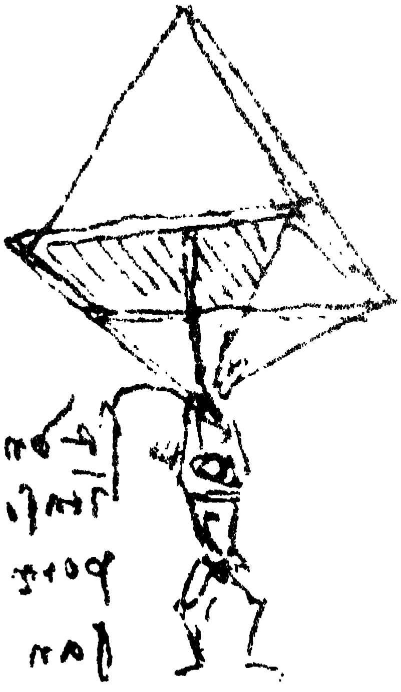
The inductive method played a crucial role in the emergence of modern trends in scientific enquiry which began with Copernicus, Kepler and Galileo and reached their pinnacle with Newton. But Aristotle's philosophy and the instruments of inquiry he had invented kept a firm hold on people's thoughts and beliefs until the European Renaissance and Reformation of the 15th and 16th centuries. Even before inductive methods could be applied to astronomy, the false premises of the geocentric universe and circular motion of heavenly bodies had to be given up; they acted as intellectual shackles, and drags, preventing new developments. They began to be broken with Copernicus but had a long way to go before they were broken completely.



Ellipses instead of circles. The dotted curves show the paths of the planets in the diagram used by Kepler to overthrow the dogma of uniform circular motion

Nicholas Copernicus (1473-1543) was a catholic monk and a contemporary of the religious reformer Martin Luther (1483-1546) and the versatile Leonardo da Vinci (1452-1519). Until his time it was an unquestioned belief, following Aristotle and Ptolemy, that the Earth is the centre of the universe; this was quite in conformity with the anthropocentric belief of the Catholic Church that man is the pinnacle of creation. To systematise geocentric astronomy Ptolemy had to introduce epicyclic motions for the planets—motions of a point on circles whose centres themselves move around on certain other circles.

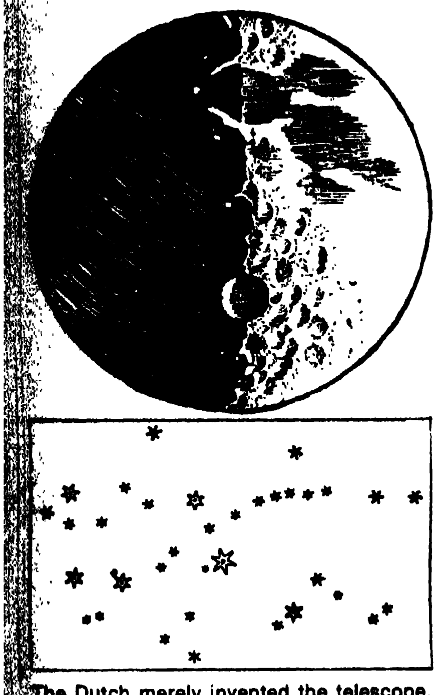
Copernicus was very much dissatisfied with this complex system. It gnawed at his mind for a whole lifetime until by a leap of thought, and with an unusual boldness in the face of the orthodoxy of his own Order and the Church, he put the Sun at the centre of things. All astronomical observations now seemed to fall into place in a simple way. We see here an audacity of the mind matched by that of Thales in stripping the theology and cosmogony of his time of the role of gods. The Copernican model, though still imperfect in many ways, initiated a revolution in basic scientific thinking which was to reach its culmination almost 150 years later in the works of Newton. This contribution of Copernicus is a supreme example of a new horizon that can be opened only by giving up an universally accepted but false premise, and of the unimaginable dividends it brings forth. Yet it was to take 2000 years to say it and openly uphold it.



Leonardo de Vinci was artist, scientist, engineer, all rolled into one. Shown above is a self-portrait and at left his sketch of a rough parachute—the first known reference to such a device

Another successful, and simultaneous, revolt against long established authoritarian dogma in Europe was spearheaded by Luther. It overthrew the more than 1000 years old Papal supremacy, brought about the Reformation and gave birth to Protestantism. What Reformation was to Christian religion, the heliocentric theory was to science. Did they have anything to do with one another? We do not know for certain. But we do know that, firstly, there had grown up by that time a social and intellectual climate which made people bold enough to question established authority when it was arbitrary and irrational. Secondly, the two revolutions occurring at the same time could reinforce each other and had a refreshing effect on the freedom of thought of succeeding generations.

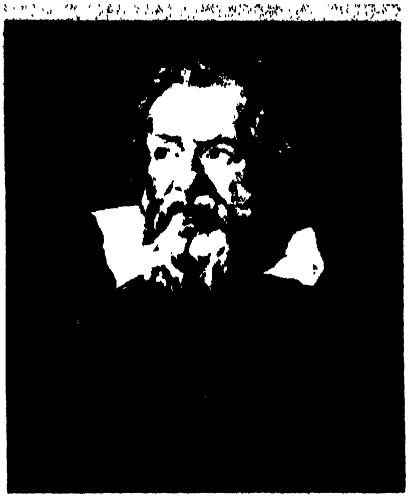
Copernicus did away with one mental manacle by replacing the concept of the geocentric universe by a heliocentric one, but the second, of the circular motion of heavenly bodies, still remained. Tycho Brahe, born three years after the death of Copernicus, was to lay an experimental base which would break it. He was a great experimentalist who devised new and accurate instruments like the quadrant and the sextant. His painstaking measurements were accurate and reliable but his theory poor. A pious and superstitious man, Brahe did not accept the Copernican system, and could not break from the dogma of uniform circular motion.


The Dutch merely invented the telescope, Galileo improved it and used it to overthrow the earlier rigid conceptions of astronomy. His 1609 sketch shows the moon as an earthly body, at A. In his *Starry Messenger* of 1610, Galileo sketches thirty-six stars in place of the then expected seven from the constellation Pleiades or the seven sisters

It was then left to Johannes Kepler to capitalise on the admirable measurements of Brahe. Working with Brahe at Prague, Kepler had access to his extensive experimental data. After putting in an incredible amount of labour and innumerable wrong guesses, he gave up circles and ovals and tried the ellipse. The ellipse worked and all of Brahe's data clicked into their place. By a method of induction Kepler generalised planetary motions. But his laws are essentially statements of fact that describe planetary motion and not a full blown theory. The third book written by Kepler, embodying a clear exposition of the Copernican theory, was proscribed by the Church. It is indeed sad to note that both these pioneers died in misfortune and penury.

We now come to Galileo Galilei (1564-1642), an experimental scientist par excellence, yet a devout Catholic all through his life. The Renaissance and the Reformation were in full swing, but Galileo's task was not any easier either with the Church or with the intellectuals of his time. Aristotelian tradition and superstition still prevailed. One of the numerous scientific contributions that Galileo made was the laws of motion of falling objects. These laws were demonstrated, as legend has it, with his experiments from the Leaning Tower of Pisa before the assembled members of the university. The experiment proved that two objects of very different weight fell to the ground together. But Aristotle had written that objects fell at different rates depending on their weight. And so the intellectuals as well as the Church refused to accept the results of the experiments to which they themselves were witnesses. So much for the power of "pure" induction!

Galileo followed up these experiments by using the newly invented telescope to study the heavens; he astounded the world by discovering a host of astronomical objects and phenomena. It is said that when invited by Galileo to view the sunspots through the telescope, the philosophers refused; they claimed that the Sun could not have spots on "rationalistic" grounds! Galileo, born 21 years after the death of Copernicus, still attempted to understand the heavens within the framework of the Ptolemaic system. Only after his discoveries with the telescope did he abandon it in favour of the Copernican scheme. The persecution of Galileo by the Church began soon after. It was in prison, in his seventies, that Galileo formulated the three axioms regarding the motion of objects and laid the foundation of mechanics—one of the outstanding contributions of his life.


Galileo Galilei, who ushered in the experimental method of modern science

Galileo's achievements in astronomy stemmed primarily from an inductive approach and, clearly, the conflict between him and the Inquisition is symbolic of that between the spirit of induction and that of deduction. Galileo looking into the sky with his telescope stripped the heavens of their age-old mystery and divinity. It is no wonder that the emergence of the experimental method and the consequent, but unexpected, discoveries in astronomy should bring forth a great proponent of inductive philosophy like Francis Bacon. He led a bitter and relentless attack on the essentially deductive philosophy of Aristotle of whom he wrote, "He did not consult experience as he should have done, but having first determined the question according to his will, he then resorted to experience and led her about like a captive in a procession."

Newtonian science

The stage was thus set for Isaac Newton (1642-1727) who was born in England the year that Galileo died. Newton was a colossus. To him goes the credit of many fundamental discoveries in physics and mathematics, each one more than equivalent to the life's work of a Nobel laureate of today. These include the binomial theorem, infinite series and differential calculus in mathematics, the spectral nature of light, refraction of light, the first reflecting telescope, the laws of motion and the law of gravitation in physics. In those days even English politicians had become aware of scientific matters and the role of scientists in discovering new knowledge. Perhaps for this reason, in contrast to the persecution and dishonour that were heaped on men like Copernicus, Brahe, Kepler and Galileo in the mainland, Newton was honoured by his country. When he died at the ripe age of 85, he was buried at the Westminster Abbey and six peers bore the pall.

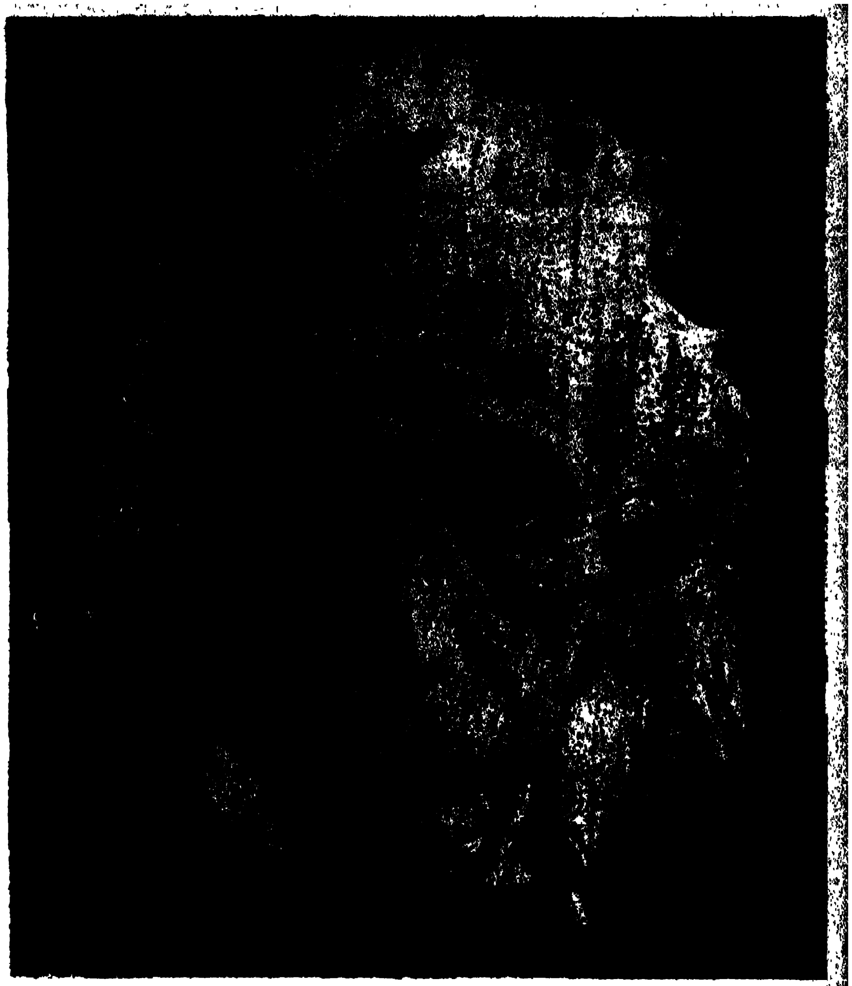
Among all his discoveries, the law of gravitation remains supreme. Kepler's laws of planetary motion represent only an elegant codification of the observed effects. But Newton's law of gravitation gave the explanation to it. This he achieved by introducing a beautiful and simple concept, that all material objects—big and small—attract one another in a simple but specific and quantitative manner. From this he went on, by deduction, to demonstrate that the same physical law which makes apples fall to the ground on Earth also governs completely the motion of heavenly bodies. In essence, he universalised a physical law for the first time.

Newton vehemently disputed the validity of hypothesisation in science and claimed his method to be one of inductive philosophy. He wrote in *Principia*, "As in mathematics so in natural philosophy the investigations of different things by the method of analysis ought ever to precede the method of composition. This analysis consists in making experiments and observations and in drawing general conclusions from them by induction and admitting of no objections against the conclusions but such as are taken from experiments or other certain truths. For hypotheses are not to be regarded in experimental philosophy."

And yet, when we examine Newton's methods carefully, they appear as typical of an inducto-deductive approach. He made use of a vast collection of earlier observational data and analysis, made his own experiments, but in trying to determine the cause of the motions of the heavenly bodies brought in a completely new conceptual idea. The rest followed by a deductive procedure from the generalised law to discrete observations and predictions.

There are some other aspects which deserve emphasis too. They root his deductions, no less important, firmly in experiments and observations. The release from the bondage of age-old traditions, myths, from erroneous first principles and from the contempt for experimental and inductive methods is a crucial element in this scientific revolution. The discoveries from Copernicus to Newton made null and void the entire edifice of scientific *theory* that was built from the time of the Greeks to the Middle Ages. In contrast, even during the scientific explosion of the modern age, the work of men like Einstein, Bohr and Chandrasekhar have not invalidated Newtonian science, but only improved upon it. All these men, from Copernicus to Newton, were also deeply religious and it does not seem to have made any difference to their scientific creativity. There does not seem to be an inherent conflict between religion as such and science.

Some of the leading methodologists of the 19th century, like John Herschel and John Stuart Mills, thought that Newton's mechanics was perfect and could not be superseded by a more general theory. Indeed, that view had become common by then. And yet we now know that though Newton's scientific contributions constitute a mighty leap forward in scientific knowledge, it was not the end of the story. That brings us to Einstein.



Einstein's theory of General Relativity

Views on the methodology of science underwent a change with the dawn of the 20th century. The eighteenth and nineteenth centuries had already witnessed an all round progress in mathematics, geometry, astronomy, physics and philosophy of science. Then Einstein, in the matter of a decade from 1904 to 1915, revolutionised science and the scientific method by his epoch-making discoveries of the Brownian motion, the photoelectric effect, the theory of Special Relativity, the equivalence of mass and energy through the famous equation $E = mc^2$, and his crowning glory, the theory of General Relativity.

In 1905, while attempting to understand the motion of objects and systems moving with a constant velocity, Einstein put forward the hypothesis that, firstly, such motions are always relative and that there is no preferred space or frame of reference, and, secondly, there is an upper limit to velocity above which no object or radiation can move and that this limiting speed is the velocity light. The introduction of these two bold and conceptual ideas, which run contrary to the very foundations of Newtonian mechanics, led to the prediction of numerous consequences. It made possible a level of generalisation in which the whole of Newton's laws of motion were not thrown out but became an approximation of Einstein's equations of Special Relativity in situations where the velocities are much smaller than that of light. That it took many decades for Einstein's predictions to be verified in the laboratory with fast moving atomic particles speaks enough for the predictive power of Einstein's deductive method.

Einstein took the deductive method of scientific discovery to a supreme height with his theory of General Relativity. Here he unified space, time and matter. The predictive ability of this theory was therefore tremendous. Einstein achieved this, essentially, by doing away with a flat geometry and bringing in certain abstract ideas of a new and sophisticated geometry invented by Gauss and developed by his student Riemann about six decades earlier. In the framework of Riemannian geometry space-time is no longer flat but curved, its curved character being equivalent to the presence of matter. The dual role of mass being simultaneously the source of inertia and gravitation, a coincidence unexplained earlier, became simply a property of Riemannian space. In the special case of a universe without matter, space-time geometry automatically became flat and the theory of Special Relativity applied.

In the theory of General Relativity, the geometry, which simultaneously describes space-time relationships between events and gravitational field, is also related to the distribution of matter in the entire universe via Einstein's equations. These equations have many solutions and represent all possible space-time geometries, that is, different kinds of universes. Thus for the first time, cosmology, which was until then in the realm of philosophy, came within the description of physics.

Induction or deduction?

Our brief look at the advance in astronomy over historical times shows that in the method of science, induction and deduction have both been important at different times. To begin with, natural philosophy was born in Ionia and Athens, some 2500 years ago, a virtual historical miracle yet to be explained satisfactorily. Beginning with Thales and continuing up to Archimedes, so many intellectual giants were packed into those few centuries amidst a strangling environment of superstition, myths and military adventurism. In spite of the popular notion about the deductive nature of Greek thought, the Ionian period lasting about two centuries saw the emergence and the application of the inductive methods to highly successful techniques. This brilliant line of thought started by Thales culminates in the fully scientific Archimedes.

Deductive methods, however, were not ignored by the thinkers of this time. Pythagoras, the originator of geometry, and also of the religious tradition, too belonged to this time. Soon after, the deductive method came into ascendancy with Plato and Aristotle. In this, geometry—the pure deductive philosophy—with its axioms and deduced theorems became the guiding method of acquiring all knowledge. But this deduction was divorced from any fruitful interaction with inductive principles. The result is the dominance of religion and the stagnation of the Middle Ages.

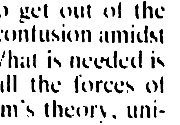
The phenomenal advances in natural philosophy, and of knowledge in general, made by the Greeks could not be improved upon for nearly 20 centuries. The next burst in science took shape during the Renaissance and Reformation when the human mind freed itself, not only in science but in all walks of life, from the bondage of centuries. In science the movement started as an escalating reaction to the Aristotelian method. The pioneers from Copernicus to Galileo had to pay dearly for their boldness in rejecting age-old tradition and superstition. Newton, who took full advantage of the extensive and accurate astronomical observations, accumulated by the labours of many scientists for almost two centuries, reinforced them with his discoveries in mathematics and built on them the edifice of Newtonian mechanics through an inducto-deductive approach.

The Newtonian system, which grew out of the reaction against Aristotle and his deductive method, looked so complete that many believed Newtonian physics to be the last word on the subject. The arrogance of such a viewpoint was compounded by the conviction that induction is self-correcting. Even C. S. Peirce says, "The validity of an inductive argument consists in the fact that it pursues a method which, if duly persisted in, must in the very nature of things lead to a result indefinitely approaching the truth in the long run."

By the time Einstein came on the scene, however, the need was for a more *deductive* approach, not an inductive one. Einstein's method was almost purely deductive and his central concept geometry. Thus in almost 2,500 years, starting with Plato, astronomy and geometry came full circle with Einstein. Of course, Einstein's deductions were firmly based on experimental work before him and, unlike Plato, Einstein was no speculative philosopher. What is important is that at some points in the inducto-deductive method which characterises science there may be a crying need for a fully deductive approach to the accumulated data and theories.

In the hierarchy of theories, those due to Galileo, Newton and Einstein present an ascending order of generality and beauty. Will we ever reach the apex of this theoretical pyramid? Einstein spent the last 30 years of his life in vain trying to develop a theory unifying the gravitational and electromagnetic fields. Einstein's theory followed by developments in quantum mechanics and more recently in high energy physics and astronomy have popularised the idea that science is, and ever will be, in a state of flux.

This also means that one must leave open the question, whether it is an inductive or a deductive approach, which is necessary to get out of the feeling of a general confusion amidst all round advance. What is needed is a unified basis for all the forces of nature. Abdus Salaam's theory, unifying the weak and electromagnetic forces and the substantial headway made in unifying them with the strong forces, is already an advance. But with the forthcoming unique opportunities of space astronomy, with so much accurate observational data collected and codified, do we need the painstaking efforts of a Tycho Brahe, or the directly inducto-deductive approach of Newton? Or, will it need someone like Einstein with a near-pure unifying concept similar to or higher than that of Riemannian geometry? Only time can tell.



Prof. Daniel, who obtained his Ph D from the University of Bristol, UK, is Senior Professor of Physics at the Tata Institute of Fundamental Research, Bombay. He specialises in cosmic ray physics, space physics, astronomy and experimental high energy physics.

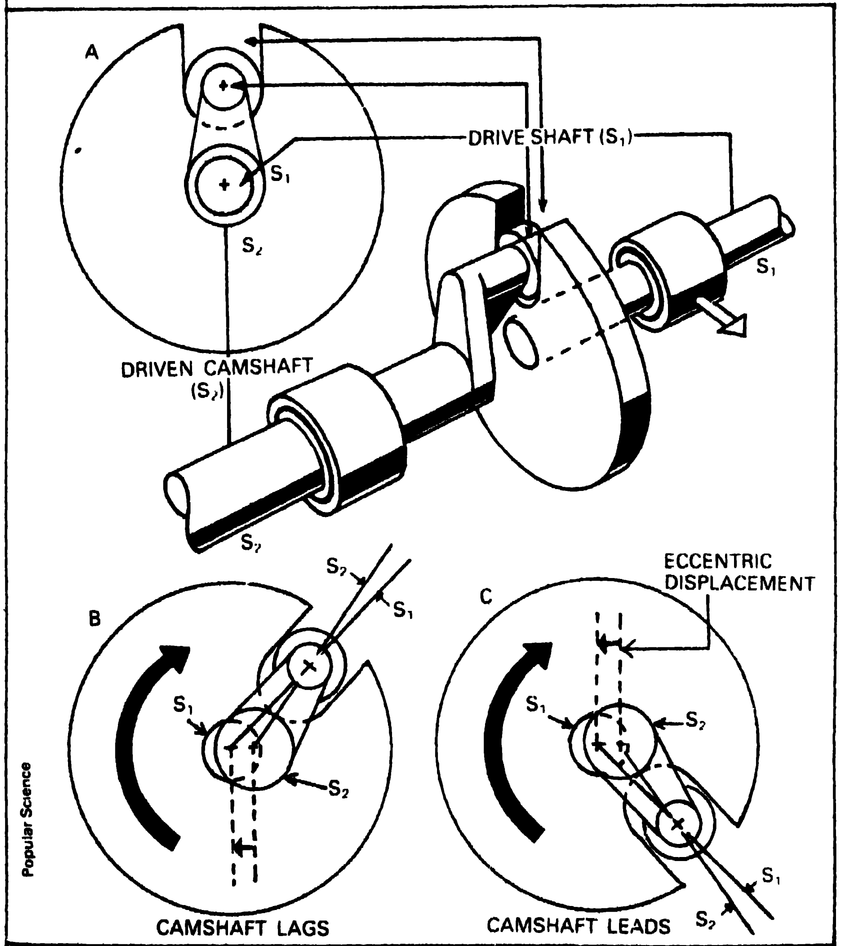
Fuel saving devices for automobiles

THE internal combustion engines used in automobiles are inherently variable speed machines. Normally, these engines operate at their peak efficiencies only at a particular speed or torque. In practice, naturally, they have to operate at a wide range of speeds. This gives rise to many problems, more so when the vehicle is used in urban areas where it is required to stop and slow down frequently due to traffic signals and congestion. Two devices now reported may lead to a better engine performance and a fuel saving of 30 to 40 per cent.

One of the problems in operating at a speed other than the optimum is inefficient combustion. Inefficient combustion is partly dependent on the closing and opening of the valves and their coordination with the engine cycle. The timing is normally taken care of by a camshaft, but the timing schedule of the valves is fixed and matched to engine performance at optimum speeds. At other speeds the same timing schedule will not ensure efficient combustion.

A solution to this problem is variable valve timing (VVT) which adjusts timing schedule to operating speed. Several engineers have tried their hand at designing such VVT devices but have been daunted by the complexity and cost of the mechanism. Stephen Mitchell, an engine designer working on VVT for the British National Research Development Corporation, has now come up with a simple VVT device (*Popular Science* **218** 2, 8). He has been able to cut down the fuel consumption of a Yamaha 250 cc engine by 43 per cent on test bed.

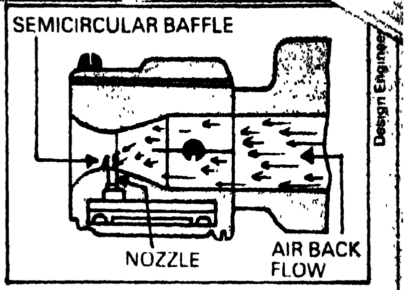
Mitchell's device requires a separate camshaft for each cylinder in the engine. He provides an eccentric or off-centre drive to the camshaft instead of the normal coaxial design. Then, even if the driving shaft rotates at a constant angular velocity, in one cycle of the rotation, the angular velocity of the camshaft is slower and faster than the average, respectively, in the two phases of the cycle. The degree of eccentricity determines how fast or slow camshafts will rotate, and can be adjusted as required to ensure more efficient timing.



Popular Science

Eccentric displacement varies valve timings. At A is shown a schematic view of the normal coaxial connection between the drive shaft and driven camshaft. When the camshaft is given an eccentric displacement, the camshaft will rotate slower and faster than the drive shaft as shown at B and C, respectively. Adjusting eccentric displacement can then change valve timing for better performance

Some hurdles, however, have still to be crossed. Separate camshafts for each cylinder will be a problem. In the test the adjustments are carried out manually. If the device is to become practicable, adjustments will have to be carried out automatically. Mitchell has proposed power hydraulic devices to effect the adjustments. Such devices have yet to be designed and tested, and the response time for feedback at such high rpm will be a problem. If Mitchell succeeds in this, it will indeed be a great step towards highly efficient engines.



Design Engineering

Semicircular baffle saves fuel wastage. Fuel is wasted due to backflow in a normal carburettor design. The semicircular baffle, guides flow to prevent wastage

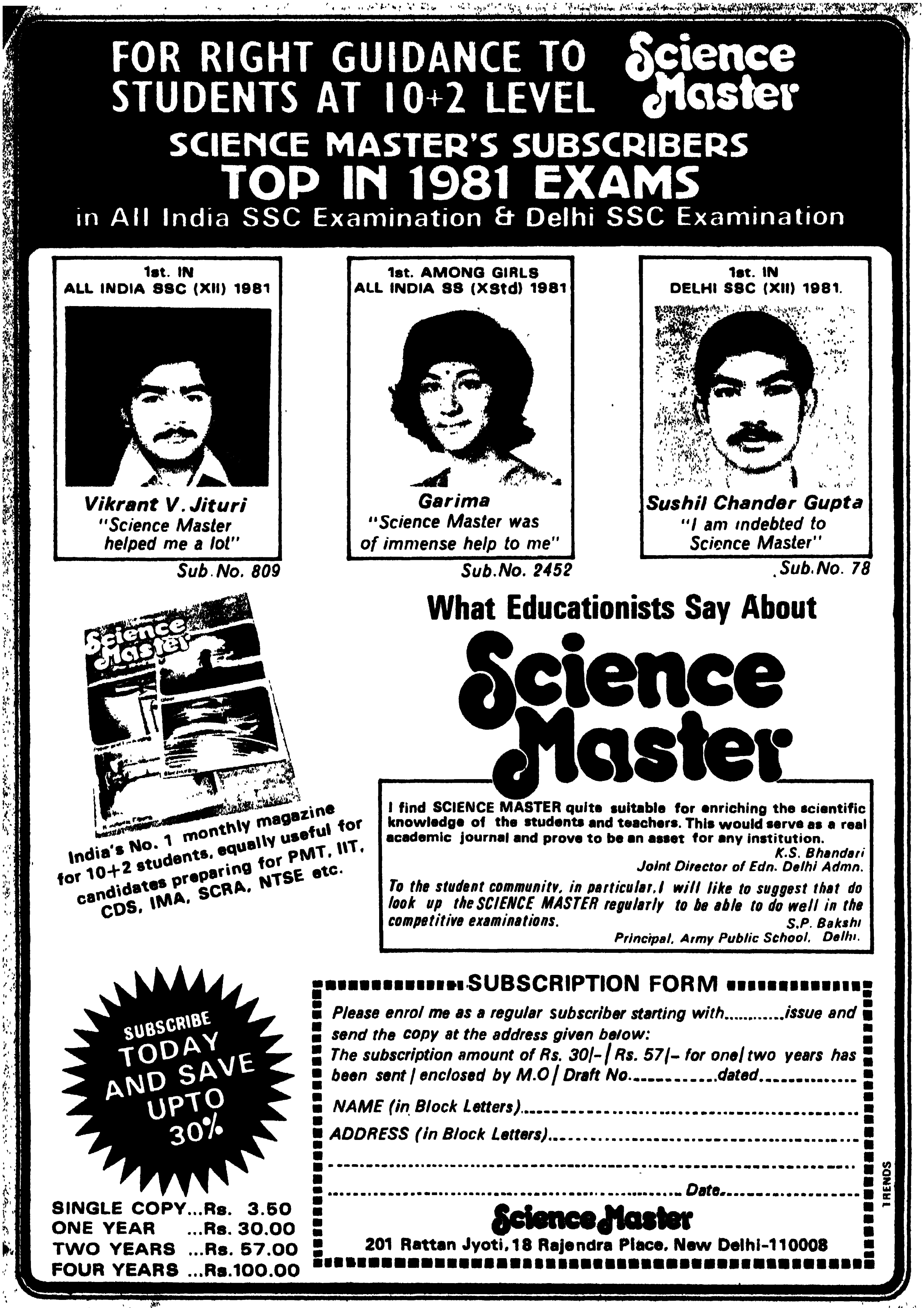
The other device is a simple modification of a carburettor fuel nozzle. It is reportedly incorporated in their latest designs by the Marvel-Schebler Tilloston Division of Borg-Warner Corporation (*Design Engineering* **62** 3, 21). In frequent stopping or varying of speed, air column resonance and reversal of air flow in carburettors lead to wastage of fuel by soaking up the air filter. The new device simply incorporates a semicircular baffle behind the carburettor fuel nozzle. This rechannels the back flowing air in the nozzle and avoids fuel wastage.

The device reportedly results in 30 per cent fuel saving in small gasoline engines. In the present fuel crisis, it is well worth, investigating whether such devices can be easily incorporated in existing engines.

S. KRISHNAMOORTHY

A. S. MENON

Dr. Krishnamoorthy and Mr. Menon are professors in the Department of Mechanical Engineering, Victoria Jubilee Technical Institute, Bombay.



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TRENDS

FUN WITH MATHS

Gap-filling of prime numbers

EVERYONE is familiar with two-digit prime numbers like 11, 13, 37, 61. If the digits are separated and the gap filled with zeroes we get a new number. Let us call such numbers gap-filled-primes, in this case, gap-filled with zeroes. Thus 1001, 100001, 200003, 307 are all gap-filled-primes. Remember, all gap-filled-primes are not prime numbers.

Gap-filled-primes derived from 11 have very interesting properties. Gap-filling with one zero gives 101, a prime number. But we need seven zeroes to arrive at the next prime number, 100000001. After 101, the next number is 1001 = 7 × 11 × 13. This explains why any three digit number written twice is a multiple of 7, 11 and 13. This is a very useful result. Similarly, 10001 = 73 × 137, which is why any four-digit number written twice has 73 and 137 as its factors. If we change the middle zero to 1, then we get 10101, a palindromic number divisible by 7 and 13. It also explains why a two-digit number written three times will have 7 and 13 as factors.

Thus, 293293, a three digit number 293 written twice, is divisible by 7, 11 and 13. 14371437, the four digit number 1437 written twice is certain to be divisible by both 73 and 137. And, 737373, the two digit number 73, written three times, will turn out to be divisible by both 7 and 13.

The next number in the series, 100001, contains four zeroes and has 11 and 9091 as its factors; 1000001 has 101 and 9901 as its factors. Both 9091 and 9901 are large primes with very special properties (which we shall consider in the next article). The next number 10000001 has 11, and a very large prime number 909091, as its factors; 1000000001 has 7, 11, 13 and a large prime number 999001 as its factors.

For students of a past generation, when arithmetic was a compulsory subject for matriculation until 1940, such results and other short cuts to calculation were very useful indeed. Even now they retain their charm for those who are fond of calculation and properties of numbers.

Let us take a look at some other gap-filled-primes. 13 gap-filled with six zeroes is itself again a multiple of 13. Similarly, 73 gap-filled with eight zeroes is divisible by 73 itself.

10000003 = 13 × 769231
7000000003 = 73 × 95890411

But 43 needs to be gap-filled with 21 zeroes to become a multiple of itself! Can you find its other factors?

The numbers 7 and 13 are common factors of many gap-filled-primes :

10000000003 = 7 × 1428571429
200000003 = 7 × 28571429
4000003 = 7 × 571429
300000001 = 7 × 42857143
100000000009 = 13 × 7692307693

Incidentally, 311 is a prime number of *three* digits and also happens to be my house number. We can bifurcate it as 3 and 11. Gap-filled with four zeroes it also has 7 as a factor.

37 and 73 are reversible prime numbers. Interestingly, 37 gap-filled with seven zeroes becomes the multiple of 73 :

30000007 = 73 × 410959

Our last example here concerns gap-filling with numbers other than zero. The prime number 13 when gap-filled with 769231 becomes a multiple of 23 and the other factor 769231!

17692313 = 23 × 769231.

D. R. KAPREKAR

Mr. Kaprekar is a retired research scholar in mathematics and has written about 25 interesting books on mathematical curiosities and short cuts. He stays at 311, Deolali Camp, Deolali 422401.

The Professor who doodles with digit powers

MY mathematician friend, Professor Longnumber is very fond of numbers of all kinds. He has a habit of "number doodling". In number doodling you start from some particular number, say a car number, a telephone number, a pin-code number, and see what sort of mathematical pecularities can be developed from the number.

It turned out that Prof. Longnumber's house number was 407. After some preliminary doodling with this number, Prof. Longnumber found to his delight that if he added together the third powers of the constituent digits, he would arrive back at the number 407. That is :

$4^3 + 0^3 + 7^3 = 64 + 0 + 343 = 407.$

He tackled his four-digit telex number in the same way, and was agreeably surprised. His telex number was 9474. Summing this time the fourth powers of the constituent digits of the four-digit number gave him the total 9474 :

$9^4 + 4^4 + 7^4 + 4^4 = 9474.$

With these two fascinating pieces of number doodling, he began to treat methodically every number he came across in his life. For a number with 'n' digits he would raise each of the constituent digits to the nth power and then sum them up in the hope that the sum would be equal to the original number. Surprisingly he found many such numbers.

His personal Savings Bank Account number 93084, had the same property,

$9^5 + 3^5 + 0^5 + 8^5 + 4^5 = 93084.$

And his pin-code number of the town where he lived, 548834 was a six-digit number with the same property.

$5^6 + 4^6 + 8^6 + 8^6 + 3^6 + 4^6 = 548834.$

This seven-digit telephone number, too, he came to love. Who else but a mathematician could fall in love with a number like 9926315? But then :

$9^7 + 9^7 + 2^7 + 6^7 + 3^7 + 1^7 + 5^7 = 9926315.$

His Life Insurance Policy number 88593477, also had this peculiar property:

$8^8 + 8^8 + 5^8 + 9^8 + 3^8 + 4^8 + 7^8 + 7^8 = 88593477.$

So did two other numbers. His driving licence number, 912985153, and his electricity consumer number, once misprinted and as 4679307774.

$9^9 + 1^9 + 2^9 + 9^9 + 8^9 + 5^9 + 1^9 + 5^9 + 3^9 = 912985153.$

$4^{10} + 6^{10} + 7^{10} + 9^{10} + 3^{10} + 0^{10} + 7^{10} + 7^{10} + 7^{10} + 4^{10} = 4679307774.$

Prof. Longnumber maintains that there are no such two-digit numbers and also that there are at least 15 such other numbers of up to ten digits. Can you think of any more? (Answers next month).

K. N. GORDHANDAS

Mr. Gordhandas is a mining engineer.

Doodling with 1981

LET us doodle around a little with the current year 1981. Repeat the number to make an eight digit number and multiply it by 1981. Thus :

19811981 × 1981 = 39247534361.

The resulting number when divided two ways (A and B below) gives some interesting properties.

392 4753 4361 ..... A
3924 7534 361 .... B

In both A and B the number that is formed by the extreme parts is 3924361 which is nothing but the square of 1981.

In both A and B the digits of the central part sum up to 19, the first two digits of the year 1981. The central part in A is equal to the sum of the extreme parts. In B the central part less the left part is ten times the right part!

Can we now get back 1981 from the three parts? In A there is at least one way. Divide the three parts by seven, we get, 56, 679, 6230. Now 56 + 679 + 2 × 623 = 1981.

Can you find other simple ways?

K. N. G.

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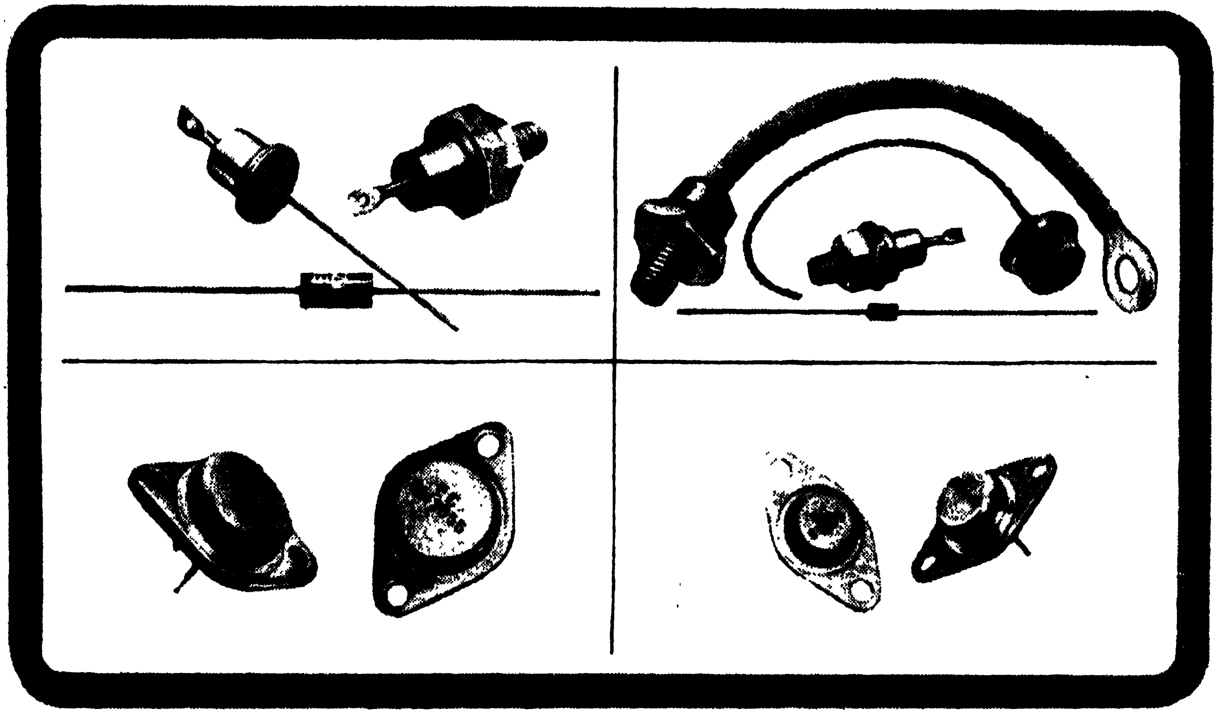

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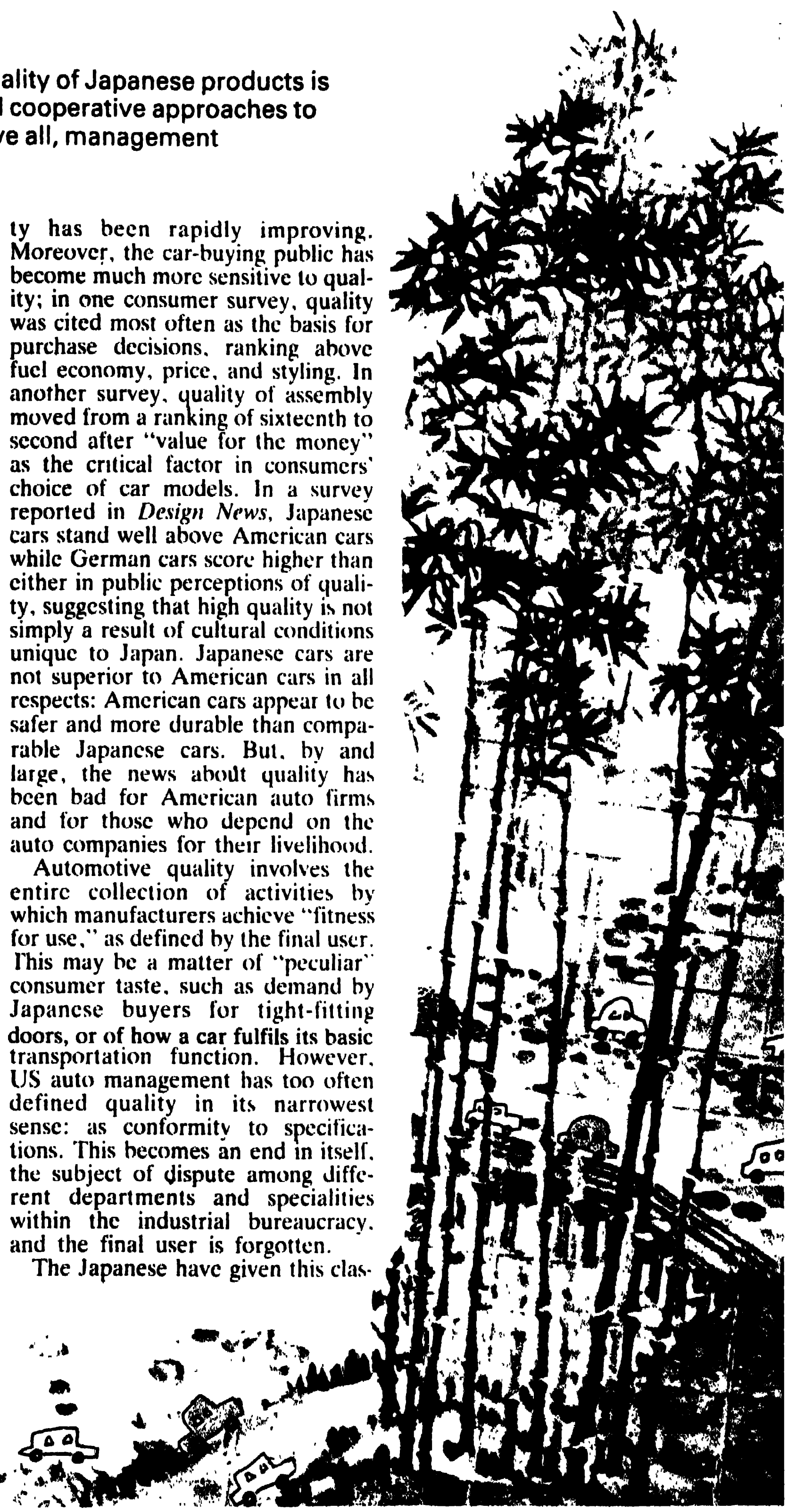
THE JAPANESE LESSON IN QUALITY

Robert E. Cole

More than skin deep, the high quality of Japanese products is achieved through innovative and cooperative approaches to design, manufacturing, and above all, management



AN estimated one out of every ten workers in automobile assembly plants is engaged in repairing substandard items, resulting in truly staggering costs for scrap, rework, retest, downtime, yield losses, and disposal of substandard components. Yet, until recently, American firms have not given product quality the high priority they reserve for other considerations such as cost reductions, prompt delivery, and production efficiency. But growing pressures from the consumer movement, the courts and government are forcing significant changes. The companies themselves are increasingly aware of the enormous costs and reduced productivity from not doing the job right the first time.

But the big factor stimulating interest in quality is the massive flow of Japanese products into the American marketplace. The Japanese have successfully used high product quality as a major *marketing* strategy. They have recognised that quality superiority can be converted into higher prices or market shares and that marketing means not only systematic selling but also knowing what is valuable to the customer.

Simply a better car

The US automobile industry recognised its own deficiencies after it suffered massive defections at the marketplace. Its own warranty-cost comparisons and consumer surveys revealed a growing gap between the essentially steady trouble frequency of American cars and the rapidly declining trouble frequency of Japanese cars. Whether this is simply a matter of fit and finish—finish of sheet metal and paint, and the accuracy with which parts fit together—is an issue of some debate. But design methods, engineering, management, and assembly processes clearly are involved.

Contrary to the popular view that American automobile quality has been declining, what in fact has happened is that Japanese auto quality has been rapidly improving. Moreover, the car-buying public has become much more sensitive to quality; in one consumer survey, quality was cited most often as the basis for purchase decisions, ranking above fuel economy, price, and styling. In another survey, quality of assembly moved from a ranking of sixteenth to second after "value for the money" as the critical factor in consumers' choice of car models. In a survey reported in *Design News*, Japanese cars stand well above American cars while German cars score higher than either in public perceptions of quality, suggesting that high quality is not simply a result of cultural conditions unique to Japan. Japanese cars are not superior to American cars in all respects: American cars appear to be safer and more durable than comparable Japanese cars. But, by and large, the news about quality has been bad for American auto firms and for those who depend on the auto companies for their livelihood.

Automotive quality involves the entire collection of activities by which manufacturers achieve "fitness for use," as defined by the final user. This may be a matter of "peculiar" consumer taste, such as demand by Japanese buyers for tight-fitting doors, or of how a car fulfils its basic transportation function. However, US auto management has too often defined quality in its narrowest sense: as conformity to specifications. This becomes an end in itself, the subject of dispute among different departments and specialities within the industrial bureaucracy, and the final user is forgotten.

The Japanese have given this classic definition a little flavour of their own. For example, Nissan and Toyota consider all those who work on the production process as customers. American auto firms have been so busy competing for maximum profits while accepting their current market share that they tended to overlook users' needs. Too often, American manufacturers have used product quality as an advertising gimmick without delivering the substance. As long as a firm's product quality was at the same level as its domestic competitors', it didn't need to worry.

Stanley Pace, president of TRW (a major automotive supplier), recently referred to Alfred Sloan's observation in the early 1920s that to gain market share against a competitor, it is not necessary to have greater-than-competitive quality. It took the raised public concern with quality, stimulated above all by the Japanese import invasion, to bring American manufacturers back to the real bottom line.

Arthur Burns, former chairman of the Federal Reserve Bank, last year attributed the poor quality of American products to the loss of the American work ethic. However, considering that the gap in quality between Japanese and American cars results almost entirely from the more rapid decline in the trouble frequency of Japanese cars, one can hardly attribute the Japanese improvements to a decline in the American work ethic. To be sure, when a plant is experiencing 15 per cent absenteeism on Mondays and Fridays, it is difficult to turn out a quality product. But, US automakers must confront the reasons for this high absenteeism.

In many automotive plants, production supervisors are under tremendous pressure from superiors to meet production quotas. All too often, employees are slapped on the wrist for poor quality but penalised severely for failing to meet quotas. This often leads workers to run substandard parts and let the final inspector or dealer worry about the resulting problems. It's no wonder that hourly employees are a little incredulous when the same supervisors mouth company quality slogans.

Some observers attribute Japan's success to superior automotive technology. Advanced technology, particularly automation, can clearly improve quality, and Japanese management is more likely to automate for this reason than American auto management. But allegations of a Japanese lead in automotive technology are highly exaggerated.

For example, early in 1980, an article in the *Washington Post* reported that the new Zama assembly plant of Nissan Motors turns out 1,300 cars a day with 67 workers on a shift, making it the world's most automated assembly plant. In reality, this plant turns out 30,000 cars a month using a standard two-shift operation, with 2,000 production workers on each shift and 1,000 support staff, a total of 5,000 employees. A US firm would need a similar number of workers to staff a new assembly plant with that kind of output. Robotics in fact account for only a small percentage of Japanese auto production. The Japanese execute known technology extremely well, but there is no evidence of a long technological lead.

Product quality is not simply the result of statistics, hard work, and advanced technology—it derives fundamentally from the application of specific management systems. Several practices in Japanese organisations have been instrumental in lifting Japan from a reputation for cheap, shoddy products to a position of world leadership in quality.

Japanese cars being loaded for export to the United States. Recently, Japan's Trade and Industry Minister, R. Tanaka, said he was "eighty per cent confident" the car dispute with the US would be settled through government-backed export restraints

Interactive design

Perhaps the greatest sources of automotive failure lie in weaknesses in engineering design. Product development and design often precede usage by several years, so it is most important to discover weaknesses during the engineering design stage. Costs are multiplied tremendously if flaws are discovered in the field.

In Japanese manufacturing firms, the product design process involves cooperative relationships throughout the organisation, including production workers. All parties take high product quality as given, reconciling their differences via discussions before final specifications are set. In the words of one high-ranking Japanese manager, "We work hard to build an overlap of different departmental skills at an early stage rather than allowing a clash of departmental interests at a later stage."

The engineers begin by issuing a design with specifications only loosely designated, describing the critical functional characteristics, hinting at the process, and defining generally the materials required. These functional characteristics relate to sales, quality, and engineering. Manufacturing, marketing, purchasing, sales, and quality-assurance staff then meet with the design staff to work out the details. Parts suppliers often become involved at this stage.

Quality considerations also play a larger role in the design of manufacturing processes, reflected in the more extensive use of statistical techniques in quality-control systems for manufacturing assembly. Finally, once the design is in production, regular modifications are made in response to feedback from the manufacturing staff and hourly personnel. By contrast, US automobile production workers or their supervisors confronted with out-of-tolerance parts will often decide to run them without informing design engineers.

The design department in US automotive firms is assumed to be relatively self-sufficient. Accustomed to a relative monopoly on product specifications, the design department tends to produce drawings with exact manufacturing details even though it is not necessarily best qualified to set parameters on reliability, maintenance, and users' costs. Feedback from other departments, although increasingly common, is often highly formal, infrequent, and too late. Moreover, quality-control personnel often lack the authority to veto engineering designs, making it unlikely that they will be able to resist pressures to meet other priorities at the expense of quality.

In US auto firms, pressures to shorten the period from product conception to production are often so extreme that fitness for use is downplayed, but this results in high testing costs and many years of "production fixes." The Japanese also try to shorten production cycles, but they recognise that good design is the key to quality, which they will not trade off against short-term savings.

We tend to look for technological fixes rather than deal with human and organisational shortcomings. For example, computer-aided design might be expected to solve some design problems. It does dramatically shorten product cycle time, and engineering designs can now also include manufacturing instructions.

Relating to vendors

Product quality depends strongly on the materials and components supplied by vendors. In US automotive manufacturing, purchased materials account for about half the manufacturing costs; the comparable figure in Japan is roughly 70 per cent. Buyers must rely on vendors as though they constituted another department. This is often not the case in the US. Vendors are treated as independent parties, and their relationship with buyers is contractual, with careful attention paid to proprietary interests. Apart from inspection, communication tends to occur only during crises. Indeed, the staff devoted to vendor assistance is minuscule and often in need of competent problem solvers.

Price competitiveness tends to dominate the selection of a vendor. Buyers draw on several vendors to sharpen competition and minimise the possibility of disruption. Vendors, in turn, often supply components to different manufacturers. Because vendors can get by with supplying merely adequate components, there is little incentive to innovate and to produce exceptional quality. Moreover, to maximise competition, manufacturers generally avoid commitment to a supplier before their designs are approved, making it impossible to involve vendors in design.

Perhaps in recognition of the more critical role of purchased parts in their industry, Japanese automakers have evolved a very different style. The relationship between vendors and buyers is one of interdependence rather than independence, cooperation rather than conflict. Because quality is crucial, buyers reject substandard components even if this slows down the production schedule and make strenuous efforts to cooperate with vendors to insure product quality.

Proprietary interests are de-emphasised, and although some major firms have strong equity positions in their suppliers, these partnerships seem no stronger than in cases where there are no such holdings. More commonly, Japanese manufacturers can increase suppliers' responsiveness to requests for improved quality and cost reductions because they draw on more than one vendor, and each vendor generally sells only to that manufacturer. To be sure, major Japanese companies have exerted tremendous pressure to squeeze cost reductions from suppliers at the expense of quality. Nevertheless, cooperation between auto manufacturers and their vendors has enhanced quality.

Vendor relations involve systematic exchange of technical, economic, and managerial information and services. Indeed, some automakers such as Toyota own joint research facilities with parts suppliers.

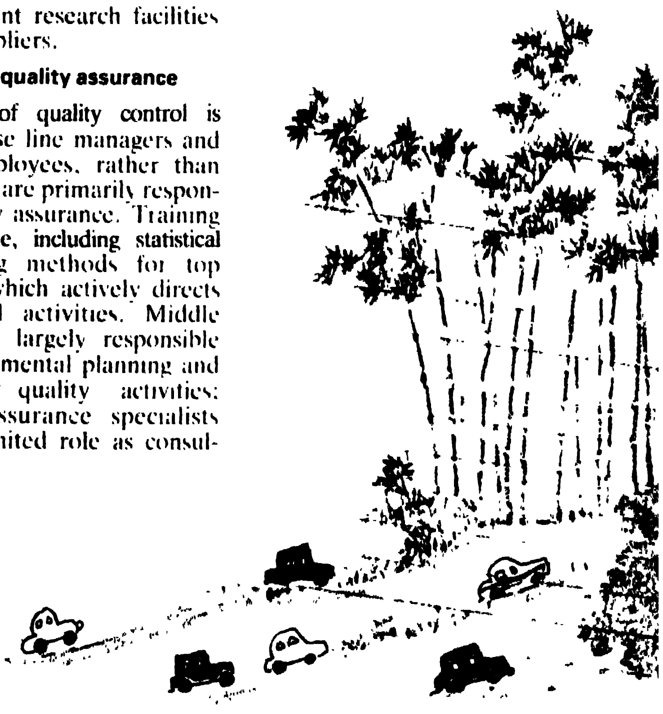
Management of quality assurance

Organisation of quality control is critical. Japanese line managers and production employees, rather than staff specialists, are primarily responsible for quality assurance. Training is company wide, including statistical problem-solving methods for top management, which actively directs quality control activities. Middle management is largely responsible for interdepartmental planning and coordination of quality activities; staff quality-assurance specialists have only a limited role as consultants and trainers. Productio[illegible]gers and supervisors assu[illegible] important role in product and p[illegible]cess planning, quality control, shop improvements, and quality-improvement programmes for workers. Finally, production workers themselves, through "quality-control circles", are encouraged to inspect their own work and trained to identify and solve shop problems.

At Toyota, workers who spot quality problems can halt assembly without consulting superiors, helping to pinpoint the exact cause. Doing the job right the first time is more than a slogan—it is built into the organisational structure. Reliance on worker self-inspection encourages attention to detail and *preventive* problem solving, reducing the costs of hiring full-time inspectors.

Thus Japanese managers treat their employees as resources that, if cultivated, will yield economic returns to the firm. Firms invest in training for all employees and emphasise development of a labour force skilled in a variety of jobs. All workers are assumed to be capable and desirous of contributing to the firm and are made to feel like fully contributing members: production workers, for instance, are on monthly salary rather than hourly wage.

By comparison, US automotive firms maintain separate and large staffs of quality specialists, including quality-control inspectors and reliability engineers with major responsibility for achieving quality. Indeed, the term "quality control" accurately



suggests the image of a police monitoring others' performance. This approach greatly emphasises continuous training for managers and staff specialists and is quite effective in establishing a formal system of quality planning and practices. But there are also significant costs. In particular, available human resources are not fully utilised. As one senior US automotive executive says, "We wrote off the workers as contributors to the organisation in the 1930s when they unionised."

US automobile assembly plants employ approximately one full-time inspector for every 20 production workers; by comparison, Toyota and Nissan employ one for every 30, resulting in significant savings and increased productivity. In US plants, the inspectors do in fact find a great deal of substandard production, but reliance on inspectors causes other employees to be less concerned about quality, which in turn leads management to hire even more inspectors.

Indeed, problems are often passed on to the dealers who receive large "dealer preparation fees" to make final adjustments and corrections. The consumer often ends up with a costlier, poorer-quality product. This cycle reveals the disadvantages of separating quality assurance from its execution.

More heads are better than one

Perhaps the most publicised Japanese innovation in quality control is the effort to involve production employees in quality assurance through the so-called "quality circles". Developed in the early 1960s, this practice has become standard at most large manufacturing firms. For example, at Toyota there are 4,200 quality-control circles for 47,000 employees, and at Nissan, 99 per cent of eligible employees participate in 4,162 quality-control circles.

The circles are in principle voluntary and autonomous study groups, though in practice there is company pressure to participate. Circles averaging ten workers apiece, usually led by the supervisor or a senior worker, meet every week or two for an hour to analyse and solve shop problems. Participants are taught elementary techniques in problem-solving, including statistical methods. In principle, workers select their own problems to work on.

The circles are geared to smallscale but continuous improvements, and the overall results are impressive. General Motors receives an average of 0.84 suggestion per eligible employee each year, of which it adopts about 23 per cent. Nissan reported in 1979 a total of nine suggestions per employee and an adoption rate of 85.7 per cent, with more than 70 per cent of these suggestions made by groups, most originating in the quality-control circles. In 1980, Toyota reported 17.8 suggestions per employee, of which it adopted close to 90 per cent. Thus, not only are Japanese firms getting more suggestions, they are getting better ones.

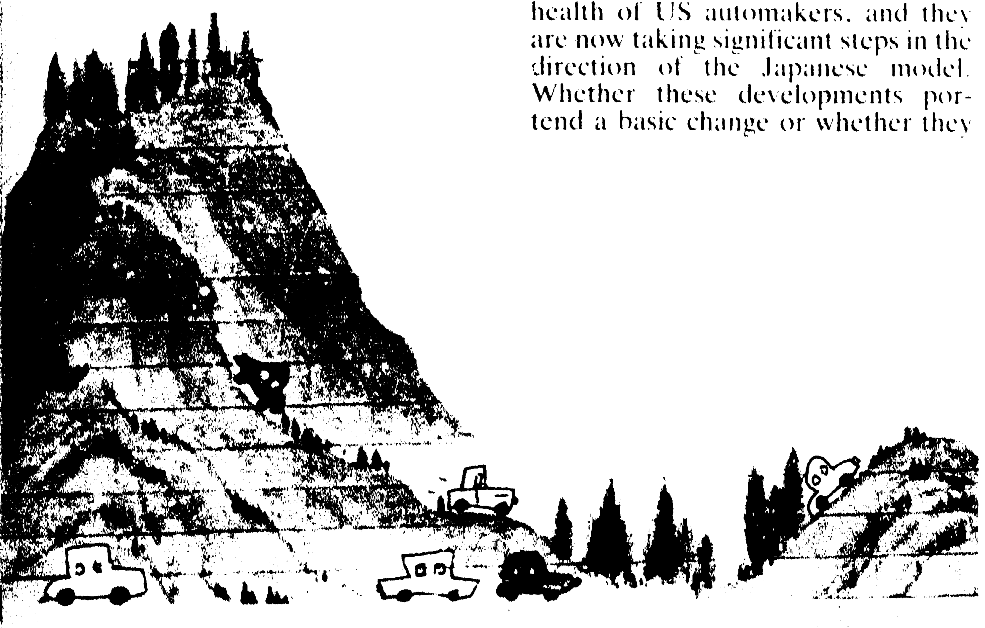
Steps in the eastern direction

The sources of the growing Japanese advantages in auto quality are, therefore, varied: Foremost is the recognition that quality and productivity are not contradictory objectives but mutually supportive. Moreover, Japanese management recognises that quality assurance can be used to achieve other desirable corporate objectives such as employee involvement in decision-making, inventory control, and increased market share.

Improved quality is vital to the health of US automakers, and they are now taking significant steps in the direction of the Japanese model. Whether these developments portend a basic change or whether they are only half-hearted efforts is open to question. In Japan, quality-control circles resulted from a long-range effort to upgrade quality and increase employee responsibility. But because many US firms are introducing the circles with little preparation and coordination with other needed changes, we will probably see a large number of initial failures.

We can in a sense reduce the Japanese approach to cooperation: manufacturing cooperates with design engineers, automakers cooperate with vendors, and management cooperates with labour. But can the US emulate this cooperative model? While it is fashionable to call for the elimination of adversarial relationships, such relationships have some real strengths. After all, the US didn't become the world leader in the automobile industry by doing everything wrong. Nevertheless, US industries would do well to encourage greater cooperation, and one place to start is with reward systems. Should the vendors be rewarded primarily for low prices or should one also place high value on quality? Should the workers be rewarded for simply following orders or for using their brains? Should manufacturing staff be rewarded merely for meeting production quotas or also for contributing to engineering design?

Women at a glove factory. Japanese employers treat their workers as resources that, if cultivated, will do good for their firms



R. E. Cole is Professor of Sociology and Director of the Centre for Japanese Studies at Michigan University, Ann Arbor, USA. This article was based on extensive interviews with automotive officials in Japan and the USA. Reprinted from *Technology Review* (July 1981), published by the Massachusetts Institute of Technology © US 1981, Alumni Association of MIT.

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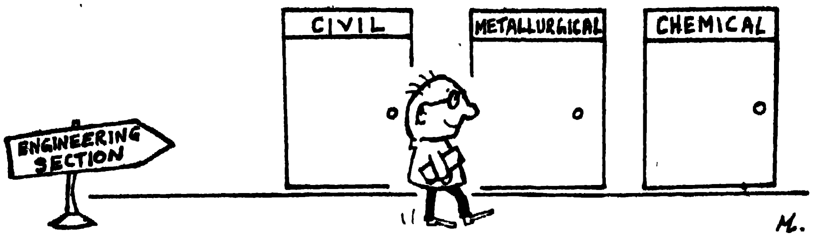
How much do you know of HUMAN GENETICS?



Much of what we are is dictated by our genes. Genetics should tell you why you are tall or short, bald or blonde. But before tackling the 16 questions given here, you could read the box below and get familiar with the terminology. Answer with brief details are on the next page.

1. The concept of the gene is a most important one in biology. Except in a few viruses, genes are composed of DNA Therefore, the gene is a unit of DNA, a particulate hereditary determiner. It is capable of self-replication, and can undergo mutation and recombination. DNA is composed of four nucleotides bases A, T, G, C. The DNA structure is usually a double helix. A gene is a length of DNA which usually consists of 900 to 1,500 nucleotide pairs. The length of the DNA double helix occupied by a nucleotide pair is 3.4 Å (1 Angstrom unit Å = 10^{-10} metre).

In man the amount of DNA per diploid cell is about 6.4×10^{9} nucleotide pairs. Assume that a man has 10^{14} cells. What would be the length of an imaginary double helix formed from the total amount of DNA in a human being?

A. 50 km
B. 8000 km
C. 65 cm
D. 220,000,000,000 km.

2. Baldness is a genetic trait expressed only in men, and not in women. True or false?

3. A couple has eight daughters. The husband claims it is the wife's fault, genetically, for not giving birth to a son. Is his claim true or false?

Gene jargon

AT THE first stage of the life process, all animals and plants start from a tiny fertilised egg-cell, which divides and grows. One kind of creature can produce only its own kind on account of genetic information stored within the sex cells. The genetic information is stored in specific hereditary units made up of deoxyribonucleic acid, DNA for short. It may be said that each gene determines a specific hereditary characteristic. The same gene usually exists in many forms, called *alleles*. The different alleles of a specific gene determine the degree to which a specific function or characteristic is expressed by the organism. The genes occupy fixed positions, or loci, on the chromosome—in fact the chromosome is a linear arrangement of genes, containing one allele at each locus.

In the body cells of man and most of the higher organisms, each of the different chromosomes is present twice. In other words, such cells have *two* alleles of each kind of gene. The organism is thus said to be *diploid*. The sex cells (sperm and ovum) are exceptions and are said to be single or *haploid*. Since the male and female supply a haploid sex cell each, the diploid nature is restored at fertilisation.

It will be important to know the use of certain symbols of genetics used in the quiz. Let's consider genes for a hereditary characteristic, curly hair, for instance. We have taken C and c to designate two different alleles of the same gene. Three possible genetic compositions (or, to use the scientific term, *genotypes*) can exist. Of these, two are *homozygous*, because they are CC and cc. The third type is the *heterozygous* Cc. Very often, the Cc individual may have as much curly hair as the CC individual. If that is the case, C is said to be the dominant allele and c the recessive allele for curly hair. Often, geneticists use other such symbols, for instance, Tt for heterozygous tallness, or DD for homozygous dwarfism, etc, as the case may be.

Remember that an individual has received genes, or DNA, from both parents. The genetic instructions from one parent may overrule the instructions from the other parent, and often the two sort of instructions for a characteristic may modify each other. An individual's total characteristics (let's forget about the acquired ones) is thus the resultant of *all* the DNA instructions. That's why children never look like twin brothers or twin sisters of their parents, while at the same time they may also "look like" mum or dad.

4. It is possible to know the sex of a baby
A. at conception.
B. a few weeks after conception.
C. only once the baby is born.

5. "Mongolism", a condition also known as Down's syndrome, is due to
A. a missing chromosome.
B. a dominant gene.
C. an extra chromosome.

6. A woman with blood group O gave birth to a male child, also with blood group O. The blood group of her husband is AB. The husband claims it is not his child. Is this claim true or false?

7. Hemophilia is a sex-linked genetic disease, where blood does not clot and the body can bleed profusely. A normal woman whose father was hemophilic marries a normal man. The couple will have
A. all normal children.
B. all hemophilic sons.
C. all hemophilic daughters.
D. the chance of half their sons being hemophilic.

8. Twins are always identical. True or false?

9. Some characteristics are transmitted exclusively from father to son. True or false?

10. The process of genes getting transformed is called
A. transformation
B. mutation.
C. evolution.

11. Children born to blonde-haired parents will
A. all be blondes.
B. all have black hair
C. have hair colour that is unpredictable.

12. Consanguinous marriages (those involving close blood relations), from a genetic point of view, is not a healthy practice. True or false?

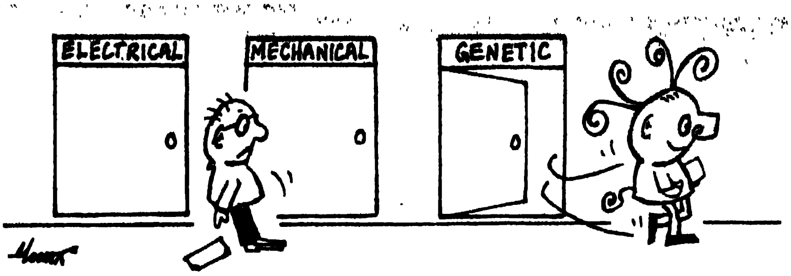
13. Children of a straight-haired father and a curly-haired mother will be
A. either curly-haired or straight-haired.
B. all curly-haired
C. all straight-haired
D. Unpredictable.

14. Late pregnancies lead to healthier children. True or false?

15. Sir Francis Galton suggested a way to improve the human race. That branch of genetics is called
A. cloning
B. eugenics.
C. recombinant DNA technique.

16. And finally, some statistics. If five babies are born at a particular hospital on the same day, what is the probability of them being all boys (or girls)?

A. 100 per cent
B. 50 per cent
C. 33.5 per cent
D. 3.13 per cent



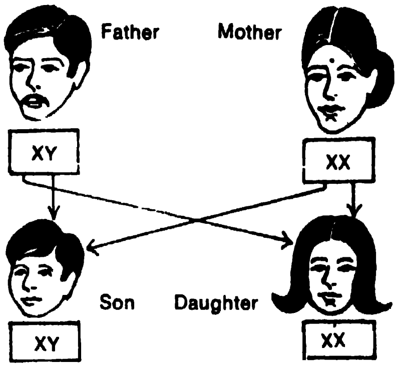
The Answers

1.—D: The length of the DNA double helix occupied by the nucleotide pair is 3.4 Å. Therefore 6.4 × 10^9 nucleotide pairs × 3.4 Å = 2.2 × 10^{10} Å = 220 cms (approx) or 2.2 metres of double helix. So, for every cell, 2.2 × 10^{14} = 220,000,000,000 km (22 × 10^{10} km). **Mind you, the distance from the** Earth to the Sun is only about 14.8 × 10^7 km.

2.—False: Premature baldness in men has been explained as a sex-limited trait (not a sex-linked trait) controlled by a gene, B. The homozygotes BB (see box) are bald irrespective of the sex. The alternate homozygotes bb are non-bald. In the case of heterozygotes, Bb, they are bald if men and non-bald if women. In other words, the allele (alternate forms of the same gene) B is dominant over b in men, but b is dominant over B in women. That's why baldness is much more common in men. This is an example of a gene where the dominance relationship of the alleles is influenced by sex.

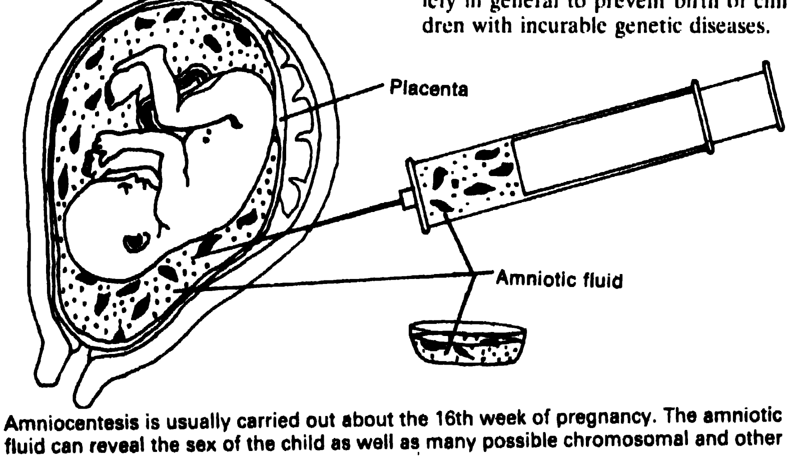
3.—False: The claim of the husband is not valid. Human cells have 46 chromosomes of which two, called the X and Y, determine sex. An XX combination leads to females, while XY leads to males. All the eggs (or ova supplied by the mother) **will be carrying an X chromosome.** So the deciding factor, whether the child would be a boy or a girl, rests with the sperm supplied by the father. An X-carrying sperm gives rise to a girl, while a Y-carrying sperm gives rise to a boy after fertilisation. In effect, the chances of a boy or girl being born are equal. So, in the above case, it is neither partner's fault, and having got eight daughters has only been a matter of chance.

4.—B: Amniocentesis is a reliable method of determining the sex of an embryo a few weeks after conception. The technique consists of mechanically drawing out some of the "amniotic" fluid that surrounds the embryo. After that, routine cytological methods are used to determine the sex chromosome constitution of the cells—XX (girl) or XY (boy).



A girl or a boy? The question is settled right at the time of conception

The cells got from the amniotic fluid can also be cultured in the laboratory for detailed chromosomal and biochemical analyses. Such analyses can reveal any gross abnormalities in the embryo. Amniocentesis offers an opportunity to potential parents in particular and society in general to prevent birth of children with incurable genetic diseases.



Amniocentesis is usually carried out about the 16th week of pregnancy. The amniotic fluid can reveal the sex of the child as well as many possible chromosomal and other abnormalities

5.—C: The disease was named after Langdon Down, who in 1866 first described the symptoms—short stature (about 4 feet tall), slanting eyes (as in Mongoloid races), stubby hands, a broad but short skull, large tongue with furrows, loose joints, particularly at the ankles, and an extremely low IQ.

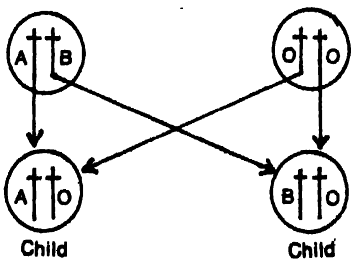
Normal human cells contain 46 chromosomes (23 pairs) Down's syndrome sufferers have an extra chromosome, and thus they have 47, one of the chromosomes pairs being actually a triplet. The disease is hence known also as trisomy.

A Down's baby

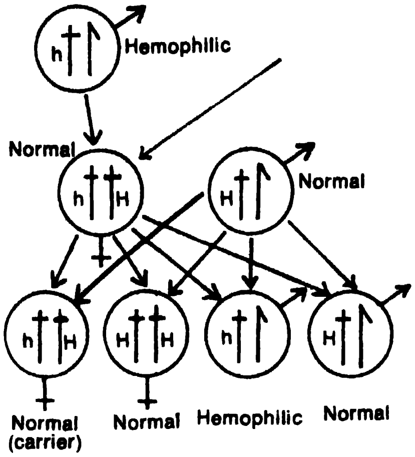
6.—True. In humans there are four major blood groups, called A,B, AB and O. These are controlled by three alleles, **A, B, and O, of the same gene. A and B are** codominant with each other and dominant over O, and how these blood groups are got can be seen in the table below:

Genotype	**Blood group**
AA	A
AO	
BB	B
BO	
AB	AB
OO	O

For the couple in question, the child can only have AO or BO genotypes, leading **to blood groups A or B, respectively. So** the child (genotype OO) must have receoved an O gene from its father, something the husband does not have. Hence the husband cannot be the father of the child. This determination would not have been possible if the husband had A, B or O blood groups. Thus blood group analyses cannot always establish fatherhood.



7.—D: It is a deficiency in the anti-hemophilia globulin that causes sufferers of the disease to bleed. Sometimes, even a slight scratch on the skin may lead to continuous bleeding and, if uncared for, the eventual death of the individual. J.B.S. Haldane, the noted geneticist and writer, examined hemophilia in the royal families of Europe and concluded that the disease is due to a recessive gene on the X chromosome. In this case the woman received theX chromosome with the hemophilic gene from her father.



Pattern of inheritance in hemophilia. Happily, hemophilia is a rare disease

8.—False: Twins can occur in two different ways. In one case, the fertilised egg divides and the two cells separate (normally they do not separate) and develop independently into two embryos. These two embryos are genetically identical, and the twins resemble each other—they are identical twins (or maternal twins). In the second case, two eggs are released (instead of the usual one) into the uterus and get fertilised by two different sperms giving rise to two different individuals (fraternal twins) who may not even resemble each other. Fraternal twins are just as similar as brothers or sisters—sometimes one may be a boy and the other a girl.

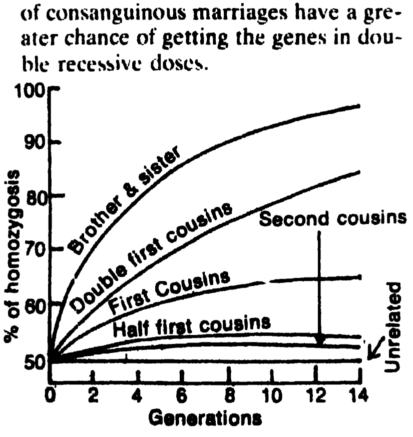
There's evidence to show that identical twins, even when reared apart, sometimes have remarkably similar lives. Mike and Peter Ball are both British bishops. Also, both Peter and Paul Warrilow became police constables

9.—True: The Y chromosome is transmitted from father to son. Characteristics controlled by genes located on the Y chromosome show this pattern of inheritance. The first established case of holandric inheritance (from mother to daughter or father to son) was reported by K.R. Dronamraju, an Indian. In 1960, basing his observations of the local Andhra population, Dronamraju reported that growth of hair on the external ear lobe (hairy pinna) is transmitted exclusively from father to son.

10.—B: Genes, which are fundamental hereditary units were thought not to undergo mutations. But, in 1927, H.J. Muler, a student of T.H. Morgan, showed that x-rays can mutate the genes. Muller was awarded a Nobel prize for his work on induction of mutations, in 1946. It is now well established that genes are made up of deoxyribonuleic acid (DNA) and the sequence of neucleotides in DNA can be changed by physical and chemical agents giving rise to mutations. Mutations provide the raw material for selection, both natural (evolution) and artificial (breeding). In short, mutations are essential for evolution.

11.—A: Genes for brown or black hair colour is dominant over blonde hair colour. So a person with blonde hair (not the peroxide ones) will have two recessive genes, in short no genes for brown or black hair. In this case, since both parents are blondes there is no chance (barring adultery) of them having children carrying genes for black or brown hair colour.

12.—True: In most cases mutations are deleterious and are recessive. In human beings, there are always two copies of any gene (except genes of the sex chromosomes X and Y in males). If a gene undergoes mutation during an individual's life span, it is not expressed because the other normal gene is present (which is dominant). When an individual carries both the mutated genes, it leads to the expression of the deleterious effect of the recessive genes. Assuming equal number of deleterious genes in all the individuals (see graph), the children of consanguinous marriages have a greater chance of getting the genes in double recessive doses.



13.—A: The curliness of hair is controlled by a dominant gene. Heterozygous individuals show curly hair, while the homozygous dominant people will have extremely curly—kinky—hair as in negroes.

In the case of the straight-haired father and the curly-haired mother, all children get a recessive gene (c) from the father, and depending upon whether they get a dominant (C) or recessive (c) from the mother, they will have curly or straight hair, chances of both being equal.

14.—False. In women, potential eggs in their ovaries begin the meiotic (cell division) process before birth and proceed to the primary 'oocyte' stage. They remain dormant there until ovulation. The oocyte completes meiosis before menstruation and one of the cells is transferred into an egg cell. The cells of a woman 40 years of age have remained inactive for twice as long as those of a 20 year old woman. This long period of inactivity increases the frequency of non-disjunction (unequal distribution of chromosomes) in the oocyte, leading to eggs with abnormal chromosomal numbers. About 40 per cent of all Down's syndrome babies are born to women over 40 years of age.

15.—B: Eugenics is defined as improvement of the genetic constitution of organisms, especially with reference to man. Galton suggested that people with superior genotypes should produce more children, and those with inferior genotypes less, or none. Although eugenics is based on sound scientific principles, social and ethical considerations stand in the way of its implementation. In fact, men have been using eugenics for plant and animal breeding quite successfully and for a very long time. Ironically, Galton, himself an unusually gifted scientist, died childless.

16.—D: 3.13 per cent. Various combinations in groups of a given-size representing a particular ratio can be calculated by expanding the binomial $(p+q)^n$, where p and q represent the probabilities of occurrence of two alternate events (p = boys, q = girls) and n is the size of the groups involved. A 1:1 ratio for instance, is assumed for boys and girls in human families. The probability of having a boy is ½ and the probability of having a girl is ½. Here five babies are born. We have to expand $(p+q)^5$ and we assume $p=\frac{1}{2}$ and $q=\frac{1}{2}$, i.e. $= p^5 + 5p^4q + 10p^3q^2 + 10p^2q^3 + 5pq^4 + q^5$. All boys or girls = p^5 or q^5 = $(\frac{1}{2})^5$ = $\frac{1}{32}$ = 3.13 per cent.

This quiz was pepared by T. NARAYAN RAO, T. GOPALAKRISHNA and R. MITRA of the Biology and Agriculture Division, BARC, Bombay.

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The options before energy planners

Energy Strategies: Toward a Solar Future *(A Report of the Union of Concerned Scientists).* Ed: Henry W. Kendall and Steven J. Nadis, Ballinger Publishing Company, Cambridge, Massachusetts, 1980, xix+320pp., softcover, price not given.

AN AVERAGE US citizen consumes approximately 2,000 times more energy than the average citizen of a third world nation. The current energy requirement is equivalent to 14 tonnes of coal or 11,820 litres of oil for every man, woman and child per year in that nation. With only six per cent of the world's population, the US consumes more than 30 per cent of the world's energy. Therefore, world attention was drawn to the energy crisis only after the crisis realisation occurred in the US. International politics and high standards of living of the US to some extent were related to its efforts to acquire cheap sources of energy at a give-away price. It engineered the destruction of the popularly elected "socialist" regime in Iran and maintained its stronghold on oil and the Arab world. The US depended on imports close to 50 per cent of its oil consumption.

US prosperity is highly dependent on adequate and regular supply of energy. However, the United States "never had a coherent, long-term strategy for assuring reliable fuel supplies and for developing satisfactory energy production, conversion, transmission, and storage technologies". Till very recently, that nation's policy governing the management of energy resources, energy pricing, energy facility regulation, and research on new energy technologies had been "capriciously and unsystematically formulated". Policy decision, has at best been merely short-term crisis management. Successive administrations failed to make a competent "technical appraisal" of the principal issues in energy policy. The energy policy formulation suffered from lack of inter-disciplinary approach and cohesiveness. Mostly due to the coal, oil and the nuclear lobbies, no serious and sincere efforts were permitted on the question of a futuristic energy policy. A major factor in the present energy crisis is that the nations of the North, while consuming the highest amounts of energy per capita, did not pay due attention to the necessary research and development efforts towards the technological options and capabilities.

Since World War II, and right up to and beyond the price hikes in world oil following the last Arab-Israeli conflict, virtually all governmental energy research and development funds were devoted to nuclear technology. Nuclear power was projected as the last and the best solution for all time to come. The official policy called for a massive nuclear power programme and it was slated to become the most dominant source of energy by the year 2000. But in less than one decade, following the economic recession, and due to strict enforcement of safety regulations and legislative watch-dog policy, the US nuclear power programme has almost collapsed. The study under review offers a thorough examination of policy records, technological data, and published and unpublished studies on energy alternatives. It has come to the conclusion that the commitment to the nuclear power programme was made "on the basis of uncritically accepted and highly optimistic technical premises" However, the study warns us against possible repeat performance in selection of future energy technologies. "Systematic, critical, and independent technical assessments" must be applied to formulation of alternative energy sources policy.

The Union of Concerned Scientists (UCS) is a voluntary organisation which has been deeply involved in examination of the basic problems connected with nuclear power. Because of the unresolved technical problems, together with the doubtful economics of nuclear power, the UCS in 1971 began its power study. For, by then, it was clear to the concerned scientists in the US that the official projections on nuclear power were highly unrealistic. It was the time when the Indian nuclear programme was just shaping up.

The UCS Energy Study group has examined the individual components of the US energy system. In terms of explicit criteria, it has attempted to provide a new comprehensive energy system that would meet the energy demands in the quantities and forms required by their energy-intensive economy. However, the study has wisely refrained from simply extrapolating growth rates for the consumption of the various forms of energy, as is the convention with the technocrats and the official analysts. Having established the wide range of future energy requirements in the major sectors of the US economy, it suggests plausible technologies that can be used to meet these demands. In their technological assessment, the Concerned Scientists have examined resource availability, technical feasibility, economics, and environmental effects Most importantly, they have tried "to apply an even-handed analysis to all of the various technological options".

However, in its conclusion the Energy Study asserts that "shrewdly selected" applications of solar energy have very favourable prospects for becoming "the basic supplier" of long-term energy requirements. They have also observed that on technical grounds solar energy systems and breeder reactors are not mutually exclusive. An energy system based on a small number of breeder reactors operating in tandem with a broad range of solar technologies would almost surely present a greatly diminished threat as compared to a full-scale plutonium economy. But it warns that the US cannot afford the costs of fully developing both solar and breeder technologies. And if the choice has to be made between the breeder and the solar technologies, the concerned scientists hold that the development of the breeder for a strictly supplemental role would entail an investment of highly questionable wisdom if it can be firmly established, as we believe it can, that renewable energy technologies are capable of performing the entire job more effectively and safely.

Based on the scientific and technological data, maps, and a host of other studies, the UCS volume draws our attention to the facts that owing to its "high thermodynamic quality, solar energy is readily adaptable to a variety of end-use tasks requiring various grades of energy. A combination of solar technologies can yield energy in all the requisite and useful forms—thermal and electrical energy and, with appropriate material inputs, liquid and gaseous fuels".

In contrast to highly financed studies sponsored by the nuclear establishments, this study acknowledges important "voluntary" contributions of many members and experts of the UCS. Fittingly, the volume carries the inscription that "this book is printed on recycled paper"

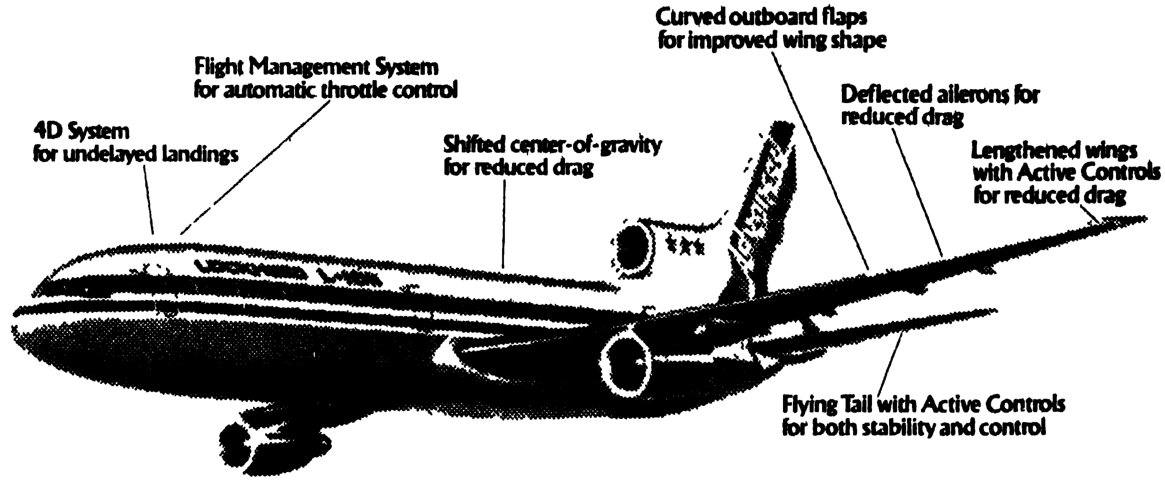
DHIRENDRA SHARMA

Dr. Sharma is with the Centre for Studies in Science Policy, Jawaharlal Nehru University, New Delhi.

AUTHOR'S CORRECT NAME

IN R. Subramanian's review of "Mathematics Education" (Books, May 1981) the author's name should read as C.V. Bhimasankaram, and not R. Bhimasankaram, as printed in the introductory panel below the review headline.

The L-1011 keeps trimming its fuel bills.


Curved outboard flaps for improved wing shape
Flight Management System for automatic throttle control
Deflected ailerons for reduced drag
4D System for undelayed landings
Shifted center-of-gravity for reduced drag
Lengthened wings with Active Controls for reduced drag
Flying Tail with Active Controls for both stability and control

Today's rising costs and shrinking supplies of fuel have posed a clear and critical challenge: find ways to pare down fuel usage.

And Lockheed L-1011 TriStar design engineers are finding those ways, without costly, time-consuming redesign of this versatile, big jetliner.

Already some major fuel-saving features have been added. The exclusive Flight Management System automatically controls the throttles for the most frugal use of fuel.

Then Lockheed's exclusive system of Active Controls reduces loads on the wings, permitting nine feet of wingspan to be added. These lengthened wings, in turn, reduce drag and save even more fuel.

Other improvements are in progress.

Lockheed has added the fourth dimension – time – to the standard navigation elements of speed, altitude and distance. It has tested a new 4D navigational capability in multiple landings at Dallas/Ft. Worth airport. And this 4D System can bring the L-1011 – within seconds – to an exact, preassigned time-and-place position for undelayed landing. No holding pattern, no wasted fuel.

The L-1011's outboard flaps will be curved 3°, making the wing shape approximate that of the most advanced, supercritical wings. That will save more fuel. Deflected ailerons already help reduce drag and save even more fuel.

Another fuel-saving advance is underway. The Flying Tail – only one on a big jetliner – will be tied into the exclusive Active Controls System. This will provide stability when the L-1011's center-of-gravity is moved aft through fuel management alterations. The result: reduced drag, increased fuel savings.

All those energy-saving advances, and more to come, are possible because Lockheed engineers designed the L-1011 to stay the most modern big jetliner in the skies. They made sure the L-1011 can accept the best new technology as it comes... today and in the future.

Lockheed L-1011 TriStar

6653/R

Flying high in foul weather

[illegible]

A JETLINER was speeding smoothly, cleaving the air nine thousand metres above the ground. Inside, two hundred passengers were happily relaxed—reading, conversing, or catching up on lost sleep. It was a summer afternoon. But for some clouds mushrooming from below, the sky was relatively clear above the hot, steaming Earth. Suddenly the aircraft shuddered. A long line of tall clouds and a few jagged streaks of light showed up ahead. As the FASTEN SEAT BELTS sign was flashed on, the plane was swallowed by billowing clouds and highly turbulent air. All outside visual references were lost to the pilot, who now had only his instruments to rely on. But even there, as the aircraft rocked viciously, he could not concentrate on the instruments panel due to "eye-ball bounce" Even if he could, the pressure altimeter and the air-speed indicator would now be erratic. The pilot felt that the aircraft was hurtling upwards in an updraught, though the indicator showed a nose-down attitude. And then, all of a sudden, the plane was caught in a downdraught that hurled it into a steep speedy dive. Within seconds the plane had plunged several hundreds of metres through the clouds. The passengers, panic-stricken, rang frantically for the stewardesses. The pilot now turned desperately to the controls. Fortunately, they proved effective and the dive was checked, just in time to avert what could have been a major disaster.

A terrifying experience, but air travellers need not be unduly alarmed by this. Considering the millions of flying hours done all over the world, accidents caused by weather are very few, thanks to the organised meteorological reporting and the consequent briefing of pilots, the inbuilt safeguards designed into an aircraft and today's pilot training. A trained pilot knows the hazards of encountering a violent thunderstorm and scrupulously avoids it.

Passenger comfort, which depends upon smooth sailing, is of prime importance. Equally important is the economy of fuel and time. The all-important flight planning depends upon meteorological support. An aircraft's operations are vitally dependent on the winds and temperatures, the adverse meteorological factors that it is likely to encounter en route, and the terminal weather conditions at the airports of departure, destination and diversion.

For instance, the meteorological office at Bombay's international airport prepares weather charts covering almost half the globe, extending from London to Tokyo, every six hours. Observations recorded simultaneously by hundreds of stations over Europe, Asia, Africa and Australia are received over high-speed telecommunication channels through a switching computer located at the Meteorological Office, New Delhi.

The observations plotted on the charts are of different types. The surface observations are recorded at the ground stations through both visual estimates and instruments. And the elements generally covered are pressure, temperature, humidity, wind, visibility, cloud cover and cloud type. In addition, upper air observations are recorded periodical-

Satellite picture of a blizzard over the USA on 25 January 1978. Blowing, drifting snow, heavy rains and hurricane winds from the blizzard disrupted aircraft operations throughout the north east for four days ly at a large number of stations by hydrogen or helium-filled balloons released into the atmosphere. These balloons carry targets which are tracked by radar, radio theodolites for wind information, and sensors which measure and telemeter the data to ground-based receiving stations. Weather satellites, both the polar-orbiting and geostationary types, provide information on cloud cover over the area of interest when monitored by ground stations. They also make available some derived information on the wind and temperature profiles in the region of scan. All these data are received within two to three hours of their time of recording and are plotted on surface and upper air charts corresponding to various levels of the atmosphere up to nearly 16,000 m above sea level. The data are then suitably analysed.

Meteorological offices at most important airports are also equipped with weather radars. They detect thunderstorms and precipitation areas and track them from the stage of development to decay within a radius of about 250 km of the stations. The data mentioned are further supplemented by observations recorded on the aircraft themselves during flight and are either transmitted to ground while in flight or handed in as "debriefing reports" as soon as the aircraft lands. These reports consist mainly of wind and temperature observations at various points en route and such other important factors as the presence of turbulence, icing, and active thunderstorms or tropical storms.

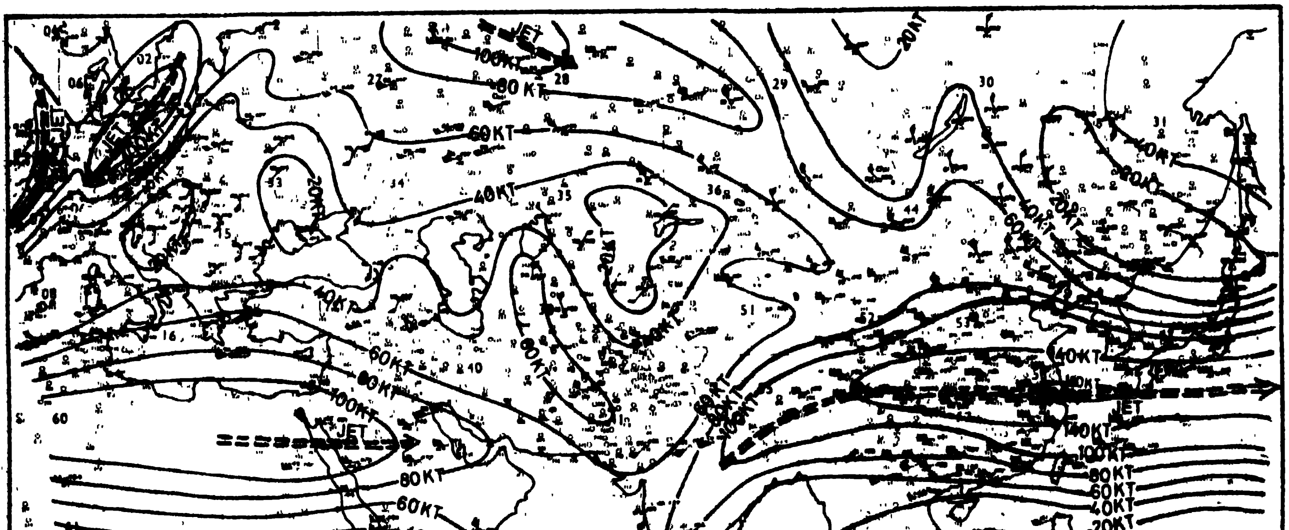
Air crew setting out on a long-haul flight lasting several hours, or their flight despatch offices, have to undertake detailed flight planning for determining the safest and most economic flight routing pattern and flight altitude. Such flight planning is generally done about four to six hours before departure.

Take the case of the wide-bodied Boeing 747, scheduled to fly non-stop from Bombay to London. The aircraft gobbles about 13,000 kg of fuel per flying hour. So, sufficient fuel for normal flying and an additional quantity of it for possible diversions have to be stocked on board. The meteorological office not only provides the weather likely to be encountered along the route, the terminal weather at the destination and the designated diversionary airfields, but also the upper winds and temperatures likely to be experienced during the ascent and descent phases and along the route so that a proper choice of flight level and routing pattern can be decided upon.

For example, in winter, strong westerly jet streams, concentrated areas of high-velocity winds generally at heights of nine to 12 km and speeds of the order of even 200 knots (knots, defined as nautical miles per hour, 1 nautical mile = 1840 m), traverse this region and are to be avoided by west-bound flights to the extent possible. Encounter with the jet core is likely to reduce the effective ground speed of the aircraft and bring about severe penalties in both time and fuel consumption. These jet streams meander and are not always located in the same place, nor are they oriented the same way every day. Meteorologists are vigilant on these areas of wind maxima, their height of occurrence, core profile and direction and keep the flight despatch office informed.

Assume that, taking advantage of this briefing, a Boeing 747 is able to save 15 minutes of flying time. This

A sample chart (below) showing the isotachs and wind maxima (jets) at the 250 mb level (about 10,500 m above sea level) on a day in the winter season. Pilots flying Bombay-London find this useful. A cloud band (left) about 6.5 km high over the Nile valley in Egypt, the Red Sea and Saudi Arabia. This cloud band is parallel to and associated with the subtropical jet stream which flows from the west. The jet streams were first encountered by American B-29 bombers during World War II on 24 November, 1944, as they set out to bomb targets in Japan



would mean carrying on board about 3,250 kg less of fuel. The same weight of cargo or about 30 additional passengers could go in instead.

Information on the surface temperature and wind, at the time of take-off, over the runway is also vital for flight planning. In the hot tropics, every degree rise in temperature could mean a load penalty of about 500 kg for certain types of jet aircraft. As for wind, a Boeing 707, for instance, can have its allowable take-off weight reduced by about 4,000 kg with a 10-knot head wind changing to a 5-knot tail wind.

International pilots are given a fully documented briefing about two hours prior to departure. This generally consists of three contour charts covering the route for the levels 300, 250 and 200 mb (corresponding to about 9,000, 10,500 and 12,000 m respectively above sea level), a significant weather chart on which factors hazardous to aviation are marked, and the forecasted and latest weather observation from the destination airport and its diversionary air fields. Many other significant data like the satellite cloud imagery, radar observations, warnings of adverse weather and flight conditions within the Flight Information Region also constitute the briefing.

Some weather hazards

Aircraft have had to depend upon the whims of nature ever since they were invented. Adverse weather is responsible not only for disastrous aircraft accidents, but also for causing flight diversions, delays and cancellations. Weather-related snarling of air traffic, can cost the world's airline companies crores of rupees annually in terms of hotel accommodation for stranded travellers and repositioning of crew and equipment.

The take-off and landing phases can be the most weather dependent. Poor visibility, very low cloud ceiling, thunderstorms and squalls, and sudden changes in windspeed or direction can be potential hazards. During cruising, thunderstorms and the associated severe turbulence, icing and hail, dust storms, mountain waves and tropical revolving storms can be the general hazards. Clear air turbulence (CAT) can also cause considerable discomfort to passengers, and if unusually intense, even some structural damage to aircraft.

Visibility

Visibility normally gets reduced in the early winter mornings when fog or thick mist develops over an airfield and there is marked temperature inversion near the ground. Visibility can also deteriorate to dangerous limits in severe summer dust storms which occur in North India. A dust storm is particularly hazardous as it combines very poor visibility conditions and turbulence. Smoke and trapped pollutants in the stagnant air over industrial cities can cause visibility deterioration to a large extent. Nearly three decades ago, the number of occasions when visibility over the Bombay airfield deteriorated below 300m was only nine in a year. The figure is now over 500.

Planes grounded at New York's JFK airport after a 50-cm snowfall. Snow covered aircraft runways are made operable today with modern snow removal methods and vehicles. Chronically fog-bound airfields are being cleared even by 'seeding the fog-layer above runways to enable aircraft to make approaches through the clear lanes thus provided

Heavy monsoon rains can temporarily reduce visibility to very low values. Usually, by the time pilots "go around" once or twice, the spell would have passed the zone of approach, improving conditions for landing.

The meteorological office constantly monitors horizontal visibility conditions either by visual estimation with the help of landmarks or with instruments. For each type of aircraft there is a prescribed meteorological minimum condition as far as visibility is concerned, below which no attempt to land is generally made. There are similar limits laid down for take-off as well. At important aerodromes a specific form of reporting visual conditions known as the Runway Visual Range (RVR) is taken recourse to. RVR reports are generally based on instrumented observations which give an idea of the visual range along the runway from the pilot's point of view as the plane approaches to land or as it takes-off. These reports take into account the level of obscurity in the atmosphere, the background illumination and the runway edge-light intensity. Major airports have computerised equipment which estimate this figure continuously.

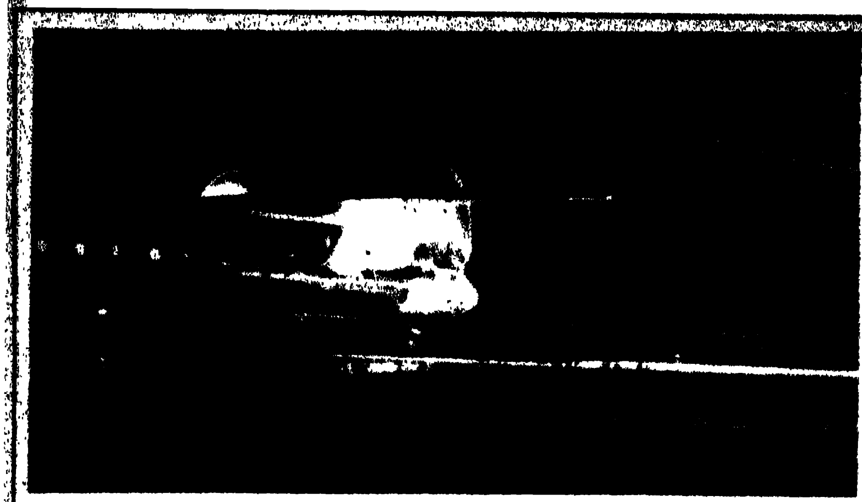
Low clouds

Landing conditions can be adverse if more than half the sky is covered with low clouds which have a base of 300m or less above the ground. Here again the meteorologist estimates the cloud height either visually or with the help of instruments at hourly or half hourly intervals. Special reports are originated whenever the base of clouds which cover more than half the sky makes transitions through the levels 300m, 150m and 60m. Stratus clouds of low base usually occur in association with heavy precipitation in the rainy season or in the cold weather period as lifting fog. With all this at hand, pilots do not attempt to land or take-off in high risk conditions unless they have other compelling reasons to do so.

Thunderstorms

Thunderstorms, by far the most dangerous weather phenomena for aviation, are caused by powerful rising currents within fully developed cumulonimbus clouds. The release of tremendous energy due to the overturning of air in the unstable layers of the atmosphere gives rise to the storms. Electrical charges that build up in the clouds produce lightning and thunder.

Thunderclouds can reach great heights over the Indian area. The average heights of tops may be around 10 to 15 km but some cumulonimbus clouds may extend even up to 20 km or more, particularly in summer. The base of these clouds generally vary from 600m to 900m above the ground. During precipitation, however, lower bases and other low cloud formations could result.



Lasers to aid aircraft landing in poor visibility. A network of ground-based laser beams called Glissada has been developed by the USSR to mark glide paths and runway boundaries. With the help of these visual aids, a pilot can land safely

Instrument landing and airborne radar systems

IF VISUAL conditions are good, the pilot takes the help of visual reference points on the ground to make a landing. In bad weather, when the seeing conditions are awful, or even otherwise, for safe landing the pilots would like to rely upon the instrument landing system (ILS)—radio and radar beams from the ground to make a safe landing. The system sends two radio beams to the incoming aircraft. One of them, called the localiser, indicates to the pilot whether the aircraft is left or right of the central line of the runway. The other, called the glide scope, indicates what the descent angle of the aircraft should be. The third aid consists of three markers along the aircraft's path indicating distances from the end of the runway. Generally the instrument landing systems in use are such that the final landing has to be made with visual references, the high intensity approach lights and the runway markings.

To fly planes automatically all the way as they approach the airport till they touchdown, a new system called the microwave landing system (MLS) is expected to be in operation at major airports all over the world by 1990s. With the MLS, which will save fuel, time and money, all kinds of aircraft will be able to land on the runway under zero visibility condition from various directions, with different speeds and angles of descent. Planes will be able to land 40 seconds apart.

The airborne radar is an invaluable instrument for detection of thunderstorm and precipitation areas ahead. The radar transmits microwave pulses and receives the energy scattered back by an obstacle. With a properly chosen wavelength and power, a radar can receive detectable energy scattered by water drops in a cloud when they reach precipitable sizes. Such radars, called "weather radars" can definitely detect thunderstorm areas (due to their high water content and large drop size) and other areas of precipitation.

The airborne radar scans the area in the forward sector and displays the echoes received from thunderstorms and precipitation areas on a Plan Position Indicator in the cockpit. Radars in fast jet planes have a maximum range capability of about 300 nautical miles (550 km) while the slower planes can make do with radar with a maximum range of 150 nautical miles (275 km). The Plan Position Indicator gives a horizontal projection of the "echoes" on the screen from where the azimuth and distance from the aircraft can be estimated. Pilots are trained to identify and interpret the echoes and they make all efforts to steer clear of the dangerous thunderstorms on their route.

J.N.

Weather radar aboard aircraft

The structure of a thunderstorm is complicated, but we know that in its mature stage when precipitation has started it is composed of up-draughts and down-draughts and vigorous eddies of such intensity that they can be dangerous to flight. A thunderstorm may have one or several cells of convective circulation which go through their life cycles of short duration, hardly an hour. Individual cell diameters may vary from 2 to 10 km. In an active, mature thunderstorm the up-draughts can reach speeds of even 48 to 50 m per sec and the down-draughts 15 to 20 m per sec. During the dissipating stage, when the up-draughts lack vigour, the top of the thundercloud spreads out horizontally, causing the characteristic cirrus "anvil" to be formed.

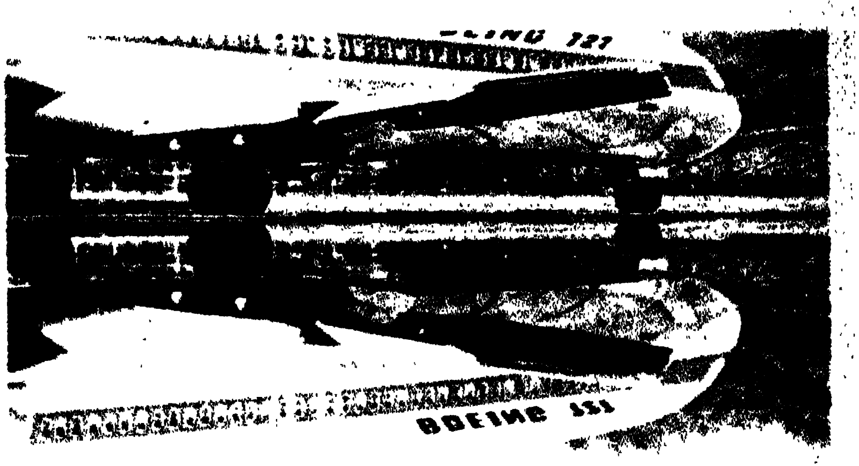
Although large thunderstorms modify the airflow in their immediate neighbourhood, most thunderstorms drift slowly with the wind prevailing in the middle and higher layers in which they are embedded. When the winds aloft are weak or variable, thunderstorms show little movement. In such cases, precipitation from the cloud is confined to a limited area and if the storm is particularly violent cloudbursts result.

The initial down-draught from the thundercloud spreads out horizontally on reaching the ground and appears as a squall at its leading edge. Wind speed in squalls may exceed 35 to 40 knots. Squalls from violent summer thunderstorms may even reach 100 knots on rare occasions. The highest squall speed occurs generally in the direction of movement of the thunderstorms. When a thunderstorm passes over a station, the prevailing wind will be suddenly changed by the on-rush of the squall. There is usually a marked fall in temperature and a surface pressure rise associated with the squall. The down-draughts from cumulonimbus clouds can sometimes trigger off the formation of other thunderstorm cells and thus regenerate successively.

Tropical revolving storms

Meteorological offices can never miss locating tropical revolving storms (called "cyclones" in these parts, "typhoons" in the Pacific, and "hurricanes" about the Caribbean) with the satellite cloud pictures and other aids being regularly available. Warnings regarding their location and direction of movement are given out at regular intervals in addition to the normal weather briefings. Since tropical revolving storms combine all the hazards of thunderstorms—heavy precipitation, high winds, turbulence

Flying conditions over mountains and between high ridges can be complicated by strong eddies and wind abnormalities. Cloud-shrouded peaks call for extra caution



An aircraft on a rain-drenched airfield. Parked and moored aircraft in tropical airfields can be affected mainly by revolving storms, thunderstorms, hail, strong surface wind and gusts, squalls, sandstorms or duststorms. Warnings are issued whenever such conditions are expected. Water-logged runways hold an element of risk to aircraft while landing or taking off

and wind shear—pilots scrupulously avoid them.

Hailstones exceeding 2 cm in diameter could affect aircraft operation, sometimes seriously. On 27 May 1959 an Indian Airlines Viscount bound for Delhi from Karachi flew into a hailstorm about 110 to 190 km west south-west of Delhi. It sustained severe damage near Sikar, Rajasthan but landed at Delhi under very difficult circumstances. The leading edges of the wings and the rudder were riddled with holes of varying sizes—some as big as 13 cm across. There were four large gashes; one on the cockpit roof, two near the aircraft nose, and another lower down on the fuselage. All this caused pressurisation failure at 5,700m and the pilot was forced to descend to a height of 2,700m. The cockpit windscreen got completely smashed due to the hail impact. But the Triplex glass, which had become opaque due to cracking, was still intact in the frames. One of the glass windows burst through the splinters and the hail hit the pilot on the head making him bleed. Apart from the holes made on the aircraft surface by hailstones ripping open the metallic cover, there were innumerable dents both large and small, some as big as 38 cm × 25 cm. The damage could be particularly severe in today's faster aircraft.

Hail is sometimes encountered even in clear air in the vicinity of thunderclouds under the cirrus canopy of the anvil—possibly one of the preferred areas where hailstones are spewed out of the cloud in violent thunderstorms.

Icing

Supercooled water drops can freeze easily on the metal frames and other parts of the aircraft. This is common when the temperature is in the region 0 to -20°C. In the case of jet aircraft, airframe icing is the predominant factor. Ice can form not only on the leading edges of the wings. It can also spread backwards over the frame causing vibrations and alterations in the aerodynamic characteristics of the aircraft. In piston-engined aircraft, icing can sometimes affect the engines themselves, particularly the air intake and induction system and the throttle mechanism. The heights at which icing can occur varies widely with the seasons and locations. The freezing level, for instance, can be as low as 1,500m over Kashmir in winter and as high as 4,500m to 5,100m in the central and southern parts of India during the summer and monsoon seasons.

Icing used to be a major problem. But now, anti-icing and defreezing devices protect crucial aircraft components.

Lightning strikes

Generally, lightning does not adversely affect metal bodied aircraft in flight except by causing radio communication failure or interrup-

Data sent back by NASA's Nimbus 7 Satellite has been used to prepare the map showing high ozone levels, indicated by the red, violet and white bands, over the North American continent. Such maps will help pilots of high-flying jet planes to choose safe routes avoiding concentrations of the highly toxic ozone gas

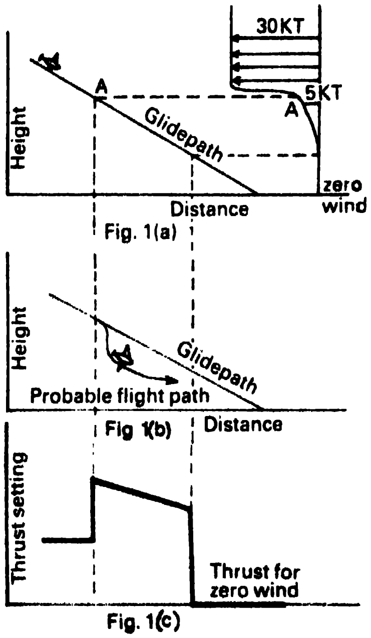


Fig. 1(a)

Fig 1(b)

Fig. 1(c)

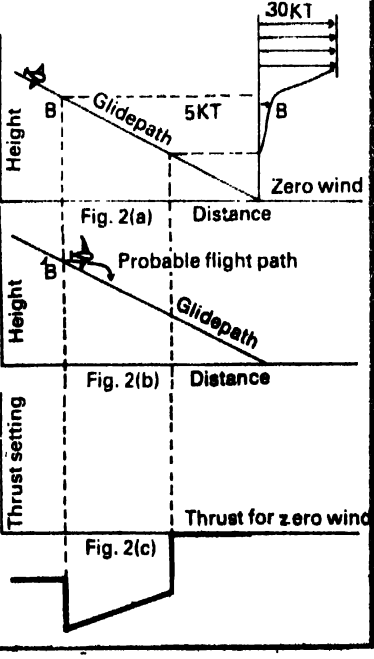


Fig. 2(a)

Fig. 2(b)

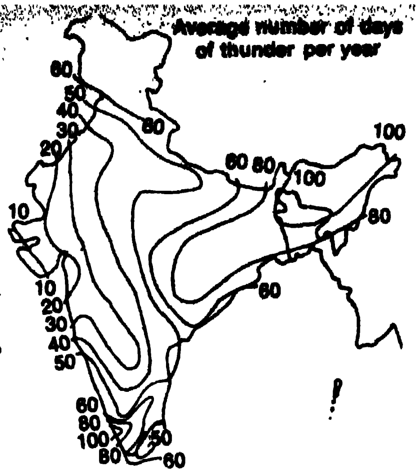
Fig. 2(c)

sion, or by flashes temporarily blinding the pilot. (SCIENCE TODAY, June 1981). Sub-zero air temperatures, heavy clouds and icy precipitation are the usual alerts against possible strikes. Choppy air, radio static or St. Elmos fire are precursors of strikes. Pilots switch on their cockpit lights and try not to let lightning flashes come in the way of their vision.

Mountain waves and CAT

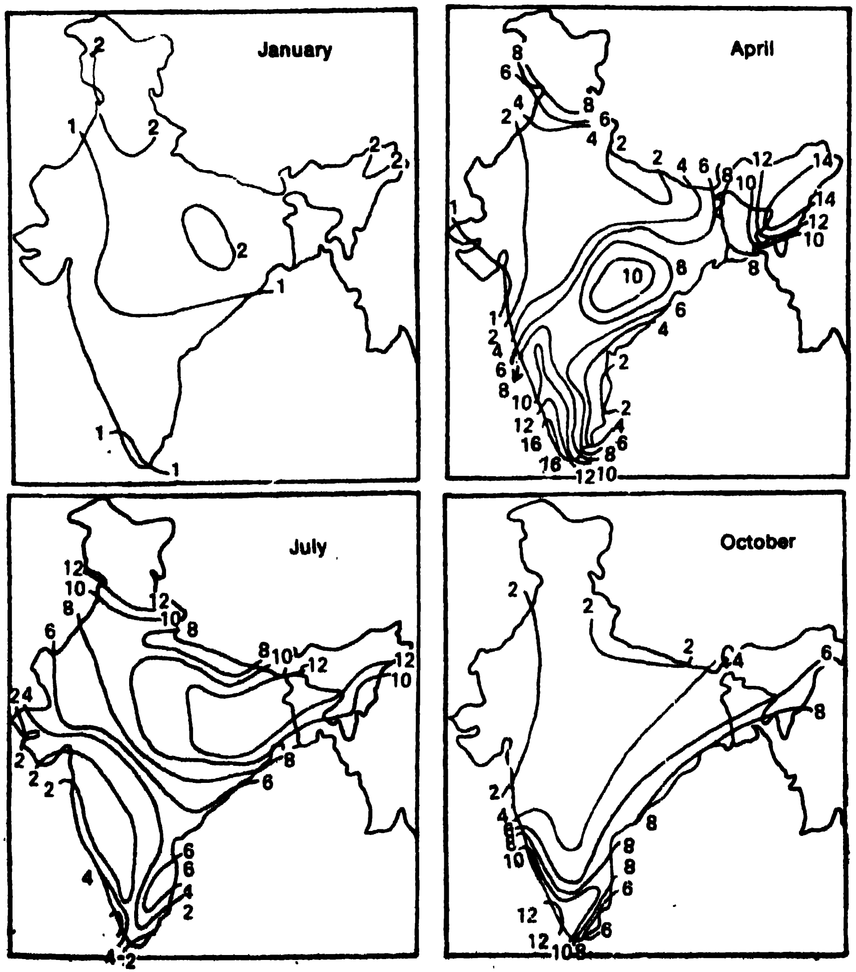
Both mountain waves and clear air turbulence develop in a generally stable atmosphere and give little visual indications to the pilot.

Mountain waves are standing waves which sometimes form on the leeward side of a range of hills or a mountain range when the wind increases with height through a stable layer. These stationary waves can extend to depths of a few thousand metres and to several times the height of the barrier causing them. Aircraft encountering these mountain waves can experience turbulence near the crest of the waves where rotor eddies form and a marked downward motion in the area immediately on the leeward side of the range and subsequent descending portions of airflow.


Average number of days of thunder per year
India Meteorological Department
80
50
40
30
20
10
80
100
60
80
100
80
60
10
20
30
40
50
60
80
100
50
80
60

Pilots do not generally risk entry into a violent thunderstorm. Neither do they normally attempt landing when approaching an airfield as the combined effects of wind shear and down-draughts could be dangerous

The average frequencies (in number of days) of thunderstorm in four typical months of the year. Violent thunderstorms develop in the pre-monsoon and post-monsoon seasons. The frequency and intensity of thunderstorm decrease during the active monsoon season. The *Kal baishakis* (Nor' westers) of Bengal and Bihar in spring and early summer are some of the most violent thunderstorms of the world



Clear air turbulence (CAT) denotes turbulence outside and away from the vicinity of clouds. It is caused by marked wind shear in a fairly stable layer of the atmosphere, when the layer breaks into eddies. The eddies can vary from 30m across to even 3,000m in size. Depending on its speed, an aircraft which passes over these eddies can experience turbulence of varying intensities and passengers may experience discomfort due to unexpected jolts. CAT is generally patchy and transient in character and its significance is that it occurs in clear air where a pilot would normally not expect problems. Meteorological offices brief pilots about where to find mountain waves and CAT.

We haven't considered the effects of these factors on the *various* types of aircraft—the slow propeller-driven aircraft, the faster turbo-prop and turbo-jet types, the supersonic, or the ultra-modern machines capable of vertical take-off—with their individual peculiarities of design and operation, heights of cruise and speed ranges. The hazards that are most important and significant to one type of aircraft may not be so to another type. At the same time, newer hazards are coming to be recognised with aircraft venturing into areas of the atmosphere hitherto not generally used for air traffic. For instance, when the SST (supersonic transport) started flying, the possibility of ozone concentrations found at the higher level of cruise affecting passengers was seriously considered and devices for minimising the harmful effects developed. Whatever be the problems, it is quite apparent that air safety is almost fully achieved when the pilot is made aware of the hazards, trained to recognise them and act correctly when encountering them. Today's aircraft are being designed and equipped to withstand many of these hazards.

Mr. Daniel is currently Regional Director, Regional Meteorological Centre, Colaba, Bombay. He has served the India Meteorological Department for over 30 years in practically all fields. His association with aeronautical meteorology has been close. In 1958 he had about a year's training in the USA in Aviation Ground Facilities. For two years he was associated with pilots training at the Indian Airlines Central Training Establishment at Hyderabad, and was the Chief Meteorologist at the Bombay International Airport from 1972 to 1976.

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TELL US...

...why nothing grows under a walnut tree?

ALL of us have seen the banyan tree with its broad canopy, and many branches with aerial roots swinging in the wind or striking roots after reaching the ground level. Nothing much ever grows under it. Necessary minerals may be present in the soil close to the roots of a newly sown seedling, but the light that drives photosynthesis is partially blocked by the canopy of the banyan tree. The walnut tree is also associated with a patch of bare undergrowth. This, in spite of the fact that there is sufficient amount of light. Of course, environmental factors are known to determine the overall structure of an ecosystem as in a banyan tree but, it seems that even certain chemicals produced by plants play a prominent role in determining the structure of the eco-system.

It is well known that individuals and populations do not live alone in nature, but in association with at least a few, if not a great many, other plants and animals. These aggregations of organisms, are not haphazard. Rather, they are perfectly ordered, utilising energy and raw materials for their survival. Such communities of plants and animals along with the environment which controls them are called ecosystems. Normally, there exists a delicate balance between the different organisms and their environments, so that the members of the community can co-exist without endangering the life of other members.

Plants produce a very large number of chemical compounds nucleic acids, cellulose, growth regulators, amino acids and proteins which are universally present and are essential for the primary metabolic processes. However, there is an array of compounds of extremely wide variety occurring in different plants, some of which show different physiological action against other plants, insects, pathogens and animals. Why do plants synthesise such compounds? The answer to some of these questions are now available as a result of researches carried out in recent years.

Plants, like other organisms, have natural enemies like other plants, grazing animals, insects, pathogens, etc. Unlike animals and insects, plants in general are stationary, and they have evolved diverse methods—anatomical, physiological and chemical—to protect themselves. Examples abound of effects of chemicals produced by plants (phytochemicals) in the ecosystem.

The inhibition of growth under a walnut tree (*Juglan* species) has been found to be due to presence of a compound called juglone (5 hydroxy-1, 4-naphthoquinone). It is present in the walnut plant, especially in leaves and roots, in non-toxic form. Rain washes it down to the soil where it gets oxidised to its toxic form.

Every one of us is familiar with the characteristic odours of some plants, which are due to their volatile constituents. A detailed study of inhibition effects of volatile constituents of *Salvia leucophylla* (Sage genus) and *Artemesia californica* (Sagebrush) has been carried out by Prof. C. H Muller and his group. It has been observed that a bare patch of land is always associated where these shrubs grow. Analysis of the soil from the base using highly sensitive physical methods has shown that volatile constituents of the plants are adsorbed by the soil. Some of the constituents which have been identified are common terpenes like alpha-pinene, camphene and camphor. Laboratory experiments have shown that these compounds do have growth inhibitory action against grasses which grow normally in the absence of these shrubs.

One of the principal interactions between plants and animals/insects in any ecosystem is the eating of some part of the vegetation by the animals and insects. But in the many million years of ecosystem evolution, some intricate and fascinating symbiotic relationships have developed.

Many plants use chemicals to deter predators. Alkaloids isolated from *Veratrum* (Hellebore) and tobacco are rather toxic and have been used as pesticides since ancient times. Rotenoids, isolated from *Derris* (Tuba) roots, and pyrethrins, isolated from the flowers of chrysanthemum species, are well known for their insecticidal actions.

Some plants have evolved novel defence mechanisms against microbial attacks. They produce a variety of antimicrobial compounds following attacks by the microbes. These compounds have been called phytoalexins. *Phaseolus vulgaris* (bean) produces four phytoalexins belonging to isoflavonoid group, following infection by tobacco necrosis virus.

Annuals inhibited by *Salvia leucophylla*. Note the bare zones in surrounding regions

Some plant chemicals defend the plants against browsing animals. For example, palatability differences between clones of reed canary grass to lambs have been correlated with the presence or absence of alkaloid in various clones. Certain vernonia species remain untouched by cattle in heavily grazed pastures. This has been found to be due to a sesquiterpenelactone glaucolide. Rather, recent researches are directed to analyse certain grasses which are specifically preferred by cattle. (SCIENCE TODAY, June 1981, p. 11).

However, chemical interactions between plants are difficult to perceive. Many fungi—moulds—are parasites on plants and cause plant diseases. Even some higher plants act as parasites, if not for food, than for space, like the strangler figs *(Ficus)*. However, in most ecosystems the principal interaction between plants is of a competitive nature. Competition occurs when one plant interferes with the needs of another for light, water or minerals or any other necessary environmental commodity. The plant may achieve the desired end-result either directly or by biochemical - suppression. The latter is by secreting potent inhibitors or toxins, which have been discussed here. Individual plants may weaken or die and populations disappear.

In conclusion, plants have developed novel mechanisms in order to survive from their many enemies and competitors. They do not have to rely on 'cosmetic spraying' where insecticides are applied in great quantities, rather indiscriminately, to produce wholesome crops. The use of DDT (dichloro-diphenyl-trichloro-ethane) has decreased considerably, not just because the chemical killed other insects, birds and animals, but because the pests started developing resistance. Such problems are not encountered by plants when they have to struggle with their natural enemies or when they have to compete for their essentials with other plants. Studies on these interactions can well give newer methods of pest control.

A. BANERJI

Dr. Banerji is with the Chemical Ecology and Pest Control Section of the Bio-organic Division, Bhabha Atomic Research Centre, Bombay.

YOU TOO CAN DO IT

IC touch switch

AN electrical circuit carrying an alternating current radiates energy in the form of electromagnetic waves, which travel in all directions. This is the phenomenon used in radio communication and broadcasting.

The electric supply in most part of India is in the form of alternating current (AC) having 50 Hertz, that is, cycles per second, as the mains frequency. Though this frequency is quite low, compared to the range of frequencies used for radio communication, this also generates a certain amount of electromagnetic waves. Thus, any conductor, including the human body, that is close to an electrical circuit can develop an induced voltage because of these waves. The low-frequency droning sound, call hum, which you hear when you touch an input terminal of an audio amplifier is due to the amplification of the tiny electric currents induced in the human body. The device explained below utilises the same effect to initiate the IC touch switch.

Use of two Integrated Circuits, IC 555 as a monostable multivibrator and IC 4027 as flip-flop, that is, bistable multivibrator, makes the unit instantly responsive to the touch signal. The use of IC 4027, C-MOS Dual JK Master Slave Flip-flop eliminates the need for using additional relay contacts in the electronic circuit.

The device basically consists of four stages: touch sensing circuit, IC 555 used as a monostable multivibrator, C-MOS IC 4027 used as a flip-flop IC bistable multivibrator, Darlington pair amplifier for operating relay and the necessary DC power supply for all these circuit stages.

In the standby state, that is, when no trigger pulse is applied to trigger terminal No. 2 of IC 555, the control flip-flop provides high output which holds the discharging transistor in conducting state, which clamps the charging capacitor 'C' to the ground level. The flip-flop also drives the inverting amplifier to provide low output. The internal voltage divider, comprising three 3 K ohm resistors in series, provides 2/3 Vcc to the upper and lower comparators, respectively. These two voltage levels thus determine the threshold and trigger levels of the two comparators.

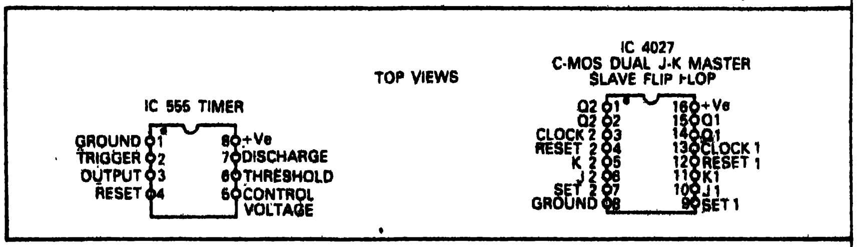
The external voltage divider consisting of 330 K and 560 K resistors and the 100 K sensitivity control potentiometer keeps the trigger terminal of the IC 555 slightly more positive than 1/3 Vcc level. When the touch plate is touched by a finger, the induced voltage at the trigger terminal of the IC 555 provides the necessary negative pulse to the trigger terminal of the IC 555. This causes the lower comparator to provide the output which changes the state of the control flip-flop from high to low. The control flip-flop, thus, cannot hold the discharging transistor and the inverting output stage provides high output at terminal No. 3 of the IC. As the timing capacitor 'C' is now unclamped, it starts charging through the 100 K resistor. When the capacitor charges to 2/3 Vcc, which is the threshold level of the upper comparator, it resets the flip-flop back to its normal high state. The flip-flop thus simultaneously discharges the timing capacitor 'C' through Q14 and brings the output again to the low level. This completes one cycle of monostable operation.

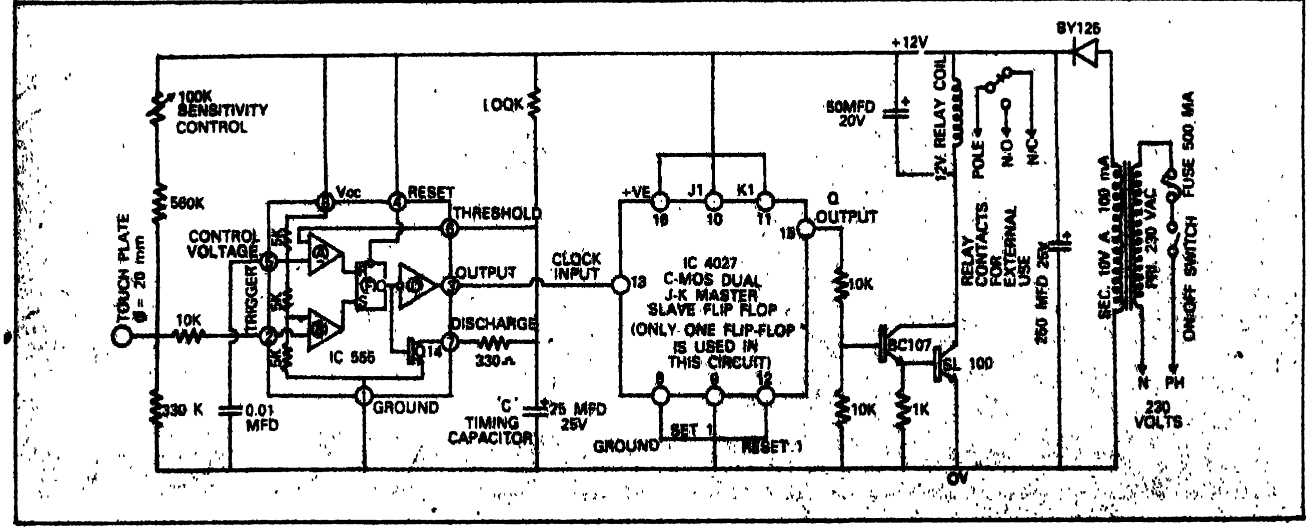
The sensitivity control potentiometer provided is for adjusting the DC voltage at the trigger terminal of the IC 555. With its maximum resistance setting, the device will have maximum sensitivity.

The output provided by IC 555, at its terminal No. 3, is fed to the clock input terminal of one of the C-MOS Dual Master Slave Flip-Flop IC 4027. When the IC 555 monostable multivibrator goes through one monostable operation, the clock input to IC 4027 drives its output from low to high. The state of output provided by IC 4027 drives its output from low to high. The state of output provided by IC 4027 remains high till IC 555 goes through one more monostable operation. The output of IC 4027 is used to drive the Darlington pair which in turn drives the 12 V relay coil.

Thus, with one touch on the touch plate, the relay changes state and remains in the changed condition till the touch plate is touched once again. The relay contact can be used to operate any electrical appliance.

The monostable multivibrator stage using IC 555 provides a monostable period of four to five seconds. This period is to avoid continuous "on-off" operation of the relay when the circuit is unable to select suitable stable state. This





phenomenon is call 'hunting'. If the touch plate remains in continuous contact with the finger, then the relay will go into the hunting action.

You may use any metal piece, about 20 mm in diameter, as a touch plate. The wiring distance between the touch plate and the trigger terminal of the IC 555 should be the minimum—less than 150 mm. If the distance is more than the connecting wire the touch plate will itself develop sufficient induced emf, which might interfere with the operation of the touch switch.

You will need

Semiconductors: IC 555 - 1 No. IC 4027 - 1 No.

Transistors: BC 107 - 1 No. SL 100 - 1 No.

Diodes: By 125 or BY 126 - 1 No.

Capacitors: Electrolytic—250 mfd - 25V - 1 No.; 50 mfd - 25 V - 1 No.; 25 mfd - 25 V - 1 No. Ceramic or polyester -0.01 mfd 1 No.

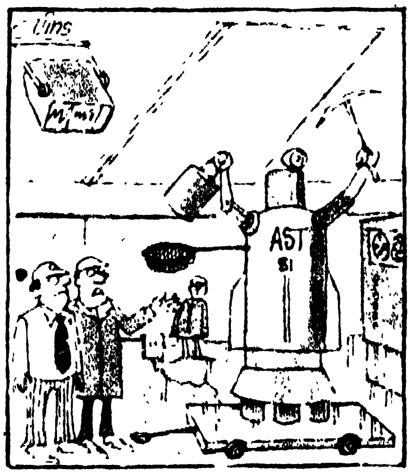
Preset or Potentiometer 100 K carbon linear — 1 No. *Resistors* (all ½ watt type): 560 K - 1 No.; 330 K - 1 No.; 100 K 1 No.; 10 K - 3 Nos.; 1 K - 1 No.; 330 ohms - 1 No.

Relay: Coil voltage 12 V DC with resistance more than 250 ohms, with two sets of changeover contacts suitable for operating the electrical equipment

Transformer (Made to order): Pri. - 230 AC. Sec. - 10V @ 100 mA - 1 No.
Approximate cost of the above electronic components in the Bombay market, Rs. 90.

Misc: On-off switch, fuse 500 mA with holder, solder, IC experimenter's veroboard, suitable enclosure, connector strip, wires, screws, mains plug, etc.

ANIL V. BORKAR



"We designed him for asteroid mining, but the boss wants us to adapt him for sea-bed nodules mining.

BRAIN TEASERS

The gardener's dilemma

THE gardener, Ram Kishan, is in a dilemma. His employer has ordered him to plant sixteen rose bushes in fifteen rows, each row containing four bushes. Failure to do this would cost him his job. How should he plant them?

P. K. MUKHERJEE

(Solution next month)

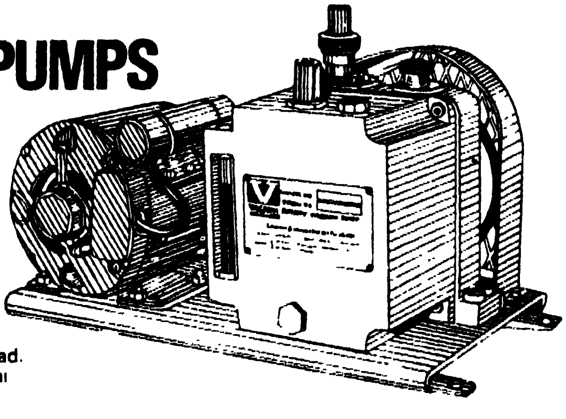
Solution to last month's Brain Teaser

Prince Charming

The newcomer had described the boy as tall and fair with a very becoming beard and wearing faded jeans and a blue shirt. The discussion that followed shows that:

1. Anand did not have a blue T-shirt.
2. Bipin could not be called fair by all.
3. Dick did not have a becoming beard.
4. Edward hated faded clothes, so would not come to college in faded jeans.
5. Farid was not tall.

Hence, the boy was Chetan.



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AWARDS AND PPOINTMENTS

WMO honour for P. K. Das

DR. P. K. Das, Director-General of Meteorology, has been invited by the World Meteorological Organisation (WMO) to deliver the next International Meteorological Organisation (IMO) Lecture in 1983. The IMO, established in 1873, was renamed World Meteorological Organisation in 1951, when it became a UN specialised agency. The lecture, which carries an award of $5000, has been instituted by WMO to commemorate its predecessor organisation.

Saha Institute Director

Dr. Manoj Kanti Banerjee, Head of the Department of Physics, University of Maryland (USA) has been nominated Director of the Saha Institute of Nuclear Physics, Calcutta, for a five-year term. Dr. Banerjee was head of the Theoretical Physics Department of the Institute till 1966.

Meteorology Award

DR S. K. Mishra and Mrs P. V. Salvekar of the Indian Institute of Tropical Meteorology, Pune, have won the World Meteorological Organisation award for 1981 with their paper on "the role of baroclinical instability in development of monsoon disturbances".

Roads Congress President

PROF. C. G. Swaminathan, Director, Central Road Research Institute, New Delhi, has been elected President of the Indian Roads Congress for 1981.

FICCI Award for Jammu Laboratory

THE Regional Research Laboratory, (RRL) Jammu, has been selected for the Federation of Indian Chambers of Commerce and Industry (FICCI) Award for 1981 in rural development. The award is in recognition of the laboratory's successful Laboratory to Land Programme.

Biogas Development Board

THE Union Government has approved the setting up of a National Biogas Development Board to boost the biogas project for the Sixth Plan period. The apex body is expected to spur the construction of biogas plants; only about 16,000 units are being constructed yearly, as against the plan target of one million. Operation Flood II, which aims at covering 10 million families and raising 10.5 million head of improved cattle, is expected to provide crucial support to the biogas plant programme.

Lady Tata Memorial Awards

THE Lady Tata Memorial Awards, for 1981, in honour of the late Lady Meherbai Dorabji Tata, have been given to Dr. B. Azzar Ne, Dr. S. Venuta and Dr. F. Lettieri of Italy, Dr. A.D. Crockard and Dr. H. J. Allen of Great Britain and Dr. H. Abrams of the United States. The international awards, which total £42,800, are given annually for study and research in blood diseases with special reference to leukaemia.

Award of American Society for Quality Control

DR Kuldip Singh Dhindsa, scientist in charge, Central Quality Testing Laboratory, Haryana Agricultural University, has been elected a member of the American Society for Quality Control. The honour is in recognition of his contributions to quality evaluation and improvement in cereals and pulses.

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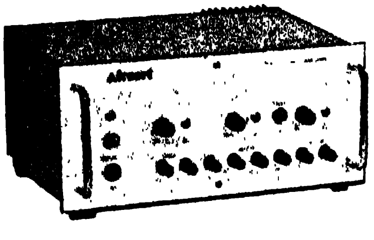

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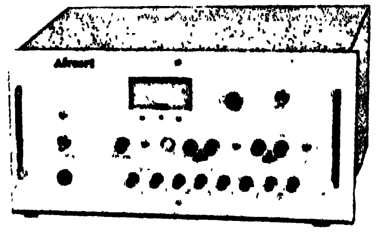

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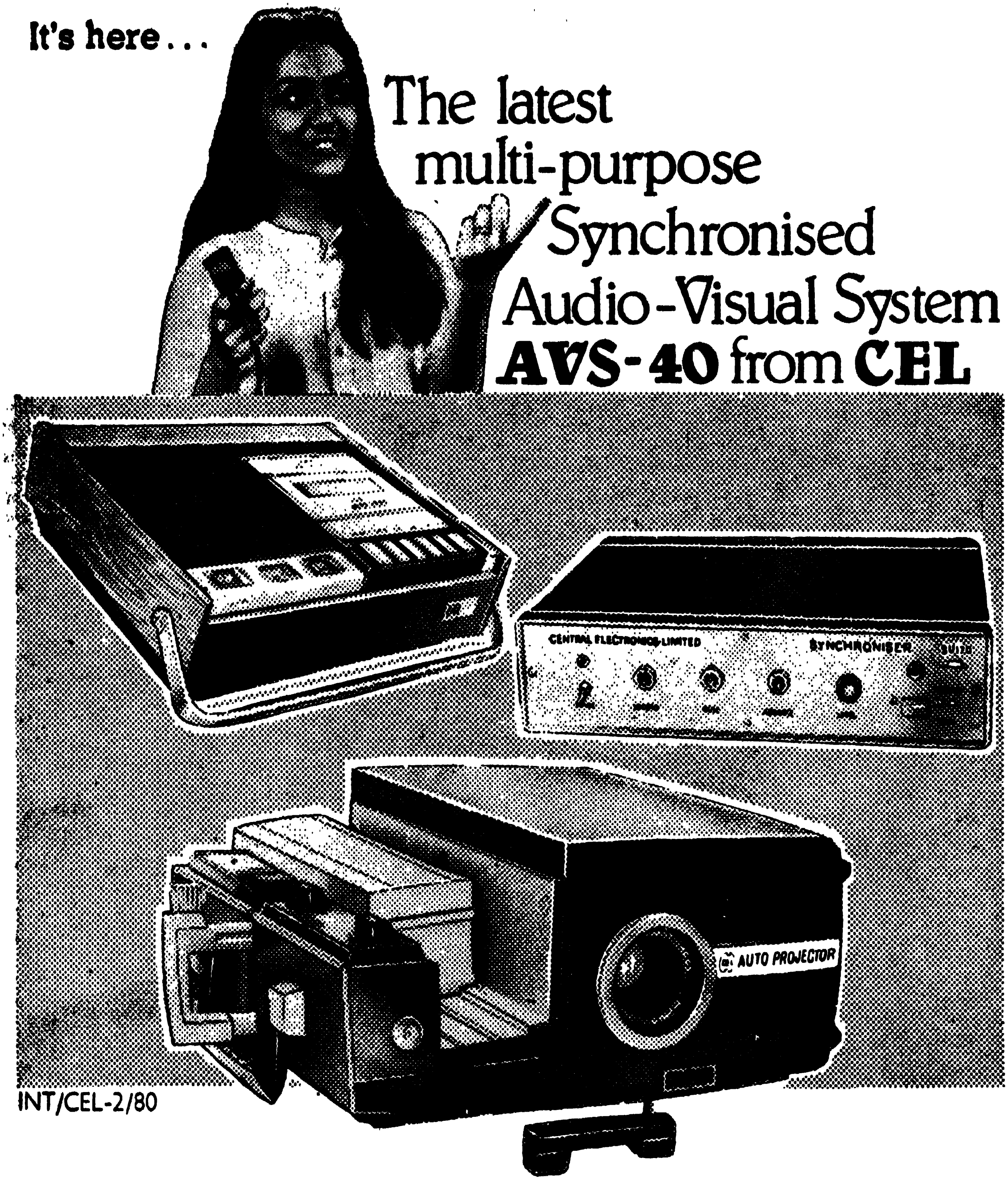

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MEETINGS CALENDAR

November

Environmental physics and atmospheric boundary layer, symp., Pune, India (K.G. Vernekar, Secretary, Organising committee, Symposium on environmental physics, and atmospheric boundary layer, Indian Institute of Tropical Meteorology, Pune 411 005). (Dates not intimated)

Microbiology of nitrogen cycling, regional training course, Dacca, Bangladesh (UNESCO). (Dates not intimated)

Hospital systems and maintenance engineering, int. conf. and show: Madras (Indian Institute of Plant Engineers, 8 Thangavelu G.St., Gokulam Colony, T.Nagar, Madras - 600 017). (Dates not intimated)

Innovations and strategies on education integrated in rural development, seminar, Islamabad, Pakistan (UNESCO). (Dates not intimated)

Role of women in the education of the child, meeting, UNESCO (UNESCO) (Dates not intimated).

4-5: Terrestrial and aquatic humic materials, symp., North Carolina, USA (Russell F. Christman, Dept of environmental science and engineering, UNC school of public health 201H Chapel Hill, North Carolina 27514, USA).

7-11: New genetical approaches to crop improvement, int. symp, Karachi, Pakistan. (Dr. K. A. Siddiqui, Convenor, Int. symp on new genetical approaches to crop improvement, Atomic Energy Agricultural Research Centre, Tandojam, Sind, Pakistan.

10-12: The opening up to women of vocational training and jobs traditionally occupied by man, int.seminar, Frankfurt, Fed. Rep. of Germany (UNESCO).

12-14: Mycotoxins, symp, National Institute of Nutrition, Hyderabad, India. (Contact not intimated)

14-16: Communication circuits and systems int. conf., Jadavpur (Prof. J.S.Chattaerjee, Dept. of Electronics and Telecommunication Engineering, Jadavpur University, Calcutta 700 032).

17-21: Low-cost equipment for science and technology education, meeting, UNESCO, (UNESCO).

17-21: Technological innovations and their social impact, symp., Bonn, Fed. Rep. of Germany (UNESCO).

18-20: Lead, zinc and cadmium: retrospect and prospect, int. seminar, Ashok Hotel, New Delhi (Indian Lead Zinc Information Centre, B-6/9 Shopping Centre, Safdarjung Enclave, New Delhi 110 029)

20-21: Reliability engineering, regional seminar, Jamshedpur, India (R. Krishnan, Hon. Secretary, The Institute of Engineers—India; Subernarekha Link, Sakchi, Jamshedpur 831 001, India)

23-25: Analyitical techniques in environmental chemistry, int. congress, Barcelona, Spain (EXPOQUIMIA, Plaza de Espana, Barcelona 4, Spain)

23-28: Physics of semiconductor devices, int. workshop, New Delhi, (Dr. T. R. S. Reddy, Secretary, International workshop on the physics of semiconductor devices. Solid State Physics Laboratory, Lucknow Road, Delhi 110 007).

25-28: Status of women, development and population trends, meeting, UNESCO (UNESCO).

26-27: Chemistry and analysis of hydrocarbons in the environment, workshop, Barcelona, Spain (Dr. J. Albaige's, Chairman, EXPOQUIMIA Plaza de Espana, Barcelona, Spain).

PHYSICAL RESEARCH LABORATORY

Navrangpura, Ahmedabad 380 009

The Physical Research Laboratory makes four awards called Shri Hari Om Ashram Prerit Dr. Vikram Sarabhai Research Awards, every two years from funds kindly donated by Pujya Shri Mota of Hari Om Ashram of Nadiad. These Awards will be made to Indian Scientists, who are not above 45 years of age, on 1st January 1981 for original work in the following fields:

(1) Electronics and Telecommunications

(2) Planetary and Space Sciences

(3) Atmospheric Physics and Hydrology

(4) Systems Analysis and Management Problems

Although the overall work of the candidates would be taken into account, the work done in India would be given primary consideration.

The candidate should have to his credit at least one or more of the following achievements:

(1) Significant achievement in scientific research

(2) Important and successful adaptation of new technology

(3) Planning, development and implementation of systems in the context of science and technology

The selections for the year 1981 will be completed by December 1981 and the awards presented on 12th August 1982.

The last date for receiving nominations is August 31, 1981. Sponsors are requested to send a two page note (12 copies) summarising the contributions and achievements of the sponsored candidate together with his her bio-data in a cover marked confidential, addressed to the Director, Physical Research Laboratory, Navrangpura, Ahmedabad 380 009. Only nominations made for the year of the award would be considered.

More detailed information will be asked for by the Selection Committee, if considered necessary.

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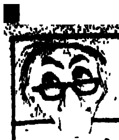


IF...

.... the sea were not salty?

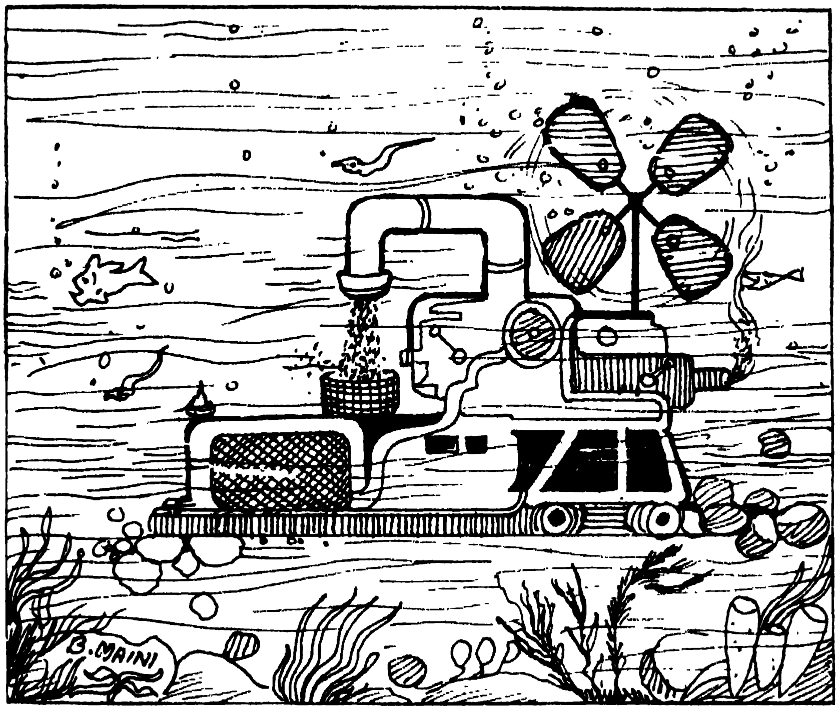
WITH burning eyes, many a choking sea bather must have wished the sea were not salty, little realising the serious consequences. The giant clams and the fabulous polymetalic nodules would then not have been there. And the Earth would have had less rains—just a few of the possible consequences of the seas being deprived of their salinity.

Of the 71 per cent of Earth's surface covered by water, 98.33 per cent is saline, 0.35 per cent fresh, and 1.64 per cent goes to form the continental ice. These salty oceans support a great variety of biomass—plants and animals—involving more than 200,000 species and presenting an incredible diversity.

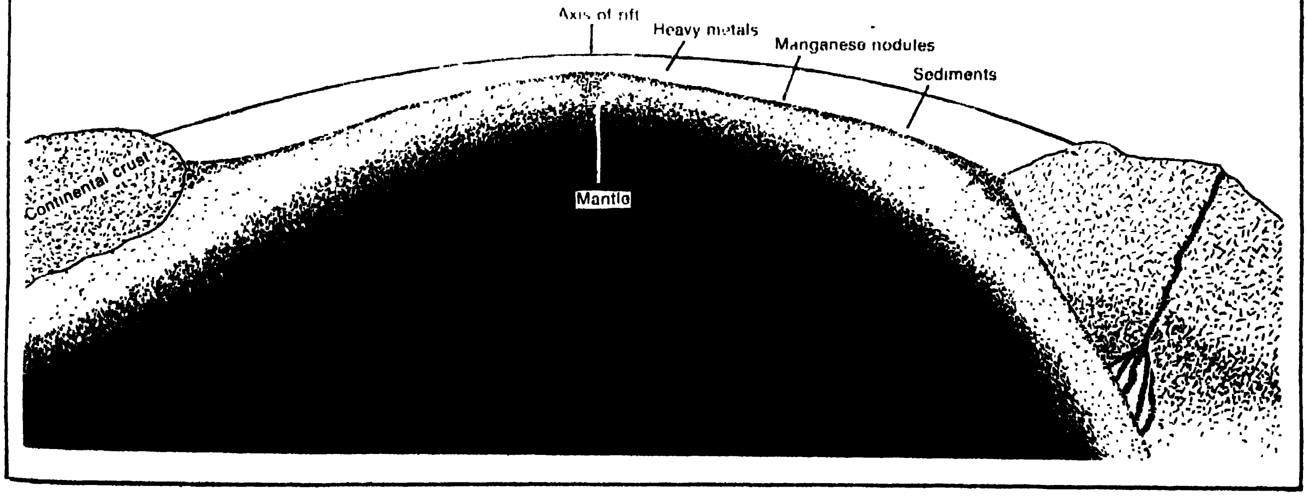
But first, how do the waters of the ocean become saline? According to a Norse folk tale, a magic salt mill continuously grinds out salt rendering the waters saline. But in geophysical terms, fresh basalt flows out from the Earth's mantle rock through the mid-ocean rift, extending over 65,000 kilometres across all the ocean floors. Accompanying it is "juvenile" water, which is derived from or existing in molten rock material. This water has never before been in the liquid phase, and contains many trace and heavy metals in addition to chlorine, bromine, iodine, carbon, boron, and nitrogen. Equally saline juvenile water is released during volcanic eruptions occurring along the continental margins. These waters, though having the same chlorine content as sea water, are more acidic due to the presence of a hydrogen ion associated with every chloride ion. But in the ocean laboratory, the hydrogen ion is replaced by a sodium ion, forming sodium chloride, common salt. The concentration of it is about 90 per cent of all the salts present, rendering ocean waters salty and alkaline.

The chemistry of the sea has a long history. Boyle, about three centuries ago, was the first to quantify the total salt content by drying the sea water and weighing the residues. Later A. L. Lavoisier separated various salts of sodium, calcium and magnesium following fractional crystallisation. In 1884, W. Dittmar analysed eight elements in 77 sea water samples collected on board *HMS Challenger* on its famous round-the-world cruise. Since then, about 74 elements in varying concentrations, including 13 rare earth elements, have been detected in the oceans. Thus, sea water is an aqueous solution containing a variety of molecules, dissolved materials, gases (especially carbon dioxide and oxygen), and suspended materials of organic and inorganic nature.

Salinity is defined as the total amount of solids in grams per kilogram of sea water, when all the carbonates have been converted to oxides, bromine and iodine replaced by chlorine and all organic matter completely oxidised. Chloride ions constitute about 55 per cent of the dissolved solids. But, is this salinity uniform over the wide stretch of the oceans? Though the average salinity of the world's ocean is about 35±2 parts per thousand, within



Left: What the mythical magic salt mill giving out salt may have looked like. *Below:* The sea's saltiness invokes the concept of "mid-ocean rift" between rigid plates in the Earth's crust. As the plates move apart very slowly, basalt from the plastic mantle of the Earth flows out, along with "juvenile" water, containing numerous elements and heavy metals. Also, at the continental margins the volcanoes are ejecting out elements and ions, which also go to make the sea salty

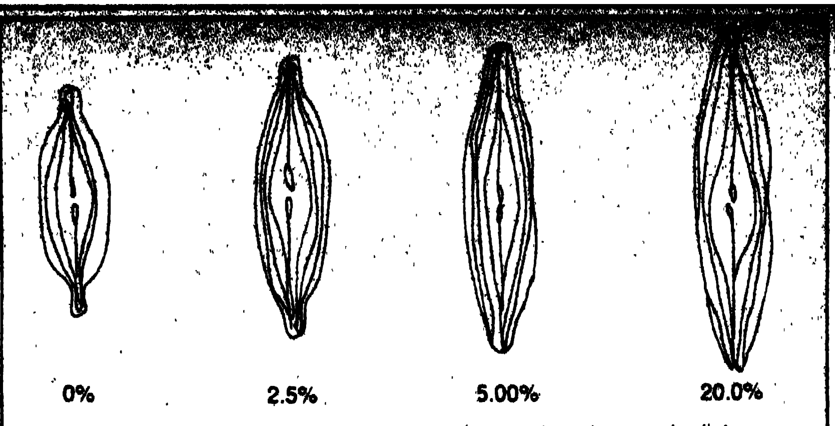


this range the surface salinity varies with the latitude—being minimum near the equator and maximum at about the latitudes 20° North and 20° South. In deep waters the salinity varies within a narrow limit of 34.6 to 35.0 parts per thousand. In isolated seas where evaporation is excessive, the salinity may reach upto 155 parts per thousand as in semi-enclosed regions in Bahamas and even upto 300 parts per thousand as in hot, brine areas of the Red Sea. The Dead Sea, with its high salinity, has many legends associated with it. Though formerly believed to be extremely sterile, today it is known that several species (though not large) of bacteria, blue-green algae, and even halophytes among a vast variety of organisms are found there. In contrast, in the coastal and estuarine zones, salinity may drop significantly with heavy rain fall and river discharges. Low salinity also occurs in polar seas through melting of ice.

The world's rivers pour about 2.7 x 10 metric tonnes of dissolved solids each year into the oceans. And yet there is no evidence at least during the last 200 million years to suggest that the total amount of salt concentration in the oceans has changed appreciably. However, the composition of ancient sediments suggests that the ratios of sodium to potassium and magnesium to calcium have risen from 1 to 28 and 1 to 3 respectively. This is because the residence time of sodium in sea water is very high.

Naturally, if the salt content were uniform the diversity in marine organisms that we see today would not be there. All possible ecological habitats are occupied by a myriad of marine populations and communities in varying numbers, depending upon their degree of tolerance to salinity changes. The populations and communities sensitive to relatively small changes in the salinity are referred to as "stenohaline" and are characteristics of open and deep ocean waters. These forms die quickly if carried by winds or currents to less saline domains. Their eggs and larvae also lose buoyancy and sink to the bottom. In contrast to these are the "euryhaline" populations and communities—the inhabitants of coastal and estuarine waters—which have evolved a great degree of tolerance to wide fluctuations in salinity. Hence they are frequently distributed in the domain of stenohaline forms too. Euryhaline species living in zones of reduced salinity are generally smaller than those of the same species from more saline waters. For example, some species of clams in the Pacific grow to a giant size with their shells measuring a metre or more in length and weighing a few tonnes. This is also true of many species of algae, invertebrates and vertebrates.

Sodium is most important in the transport of metabolites into the cells of all living matter though the salts of the other major elements, potassium, calcium and magnesium, also play a major role in preserving the integrity and perfect functioning of the cell. It follows that, less saline waters would affect functional and structural properties of the organisms, which will ultimately lead to reduction of reproductive potentials and biological activities of organisms. No wonder the species from fresh water regimes are found to be significantly smaller than their saline water counterparts. Various communities of marine species—fish, crabs, lobsters, prawns, oysters, clams and algae harvested for economical uses, are found damaged when the ambient salinity is dramatically reduced by heavy rains or river discharges. A good catch of fish or giant lobster will no more be there. And the coral reef formation, a most fascinating example of marine biological activity in tropical oceans, will be significantly affected if there is a persistent great fall in the salt concentrations of their natural habitats



Effect of salinity changes on the shape and size of a microscopic diatom

How would human civilisation have been affected if the many trace and heavy elements which are found in the ocean floors were absent? The presence of many trace and heavy elements was detected in marine animals and plants before their detection in ocean waters. It is an interesting historic fact that within less than a decade of the discovery of the element iodine in 1811 by Courtois, it was measured in high concentrations in marine sponges and corals, much before it was detected in the ambient waters. Similarly, in 1960, the cosmic ray-produced isotope Silicon-32 was first detected in marine sponges by D. Lal. Many marine organisms are thus found to be the "storehouses" of trace and heavy elements. It is also interesting to know that while concentrating these elements, the organisms show preference for a particular element or group of elements. Similarly, there are also inorganic processes through which many minor elements are concentrated. The classic example of this is the formation of polymetallic manganese nodules (SCIENCE TODAY, June 1981) which are found to accumulate elements such as thallium and platinum in addition to cobalt, nickel, copper, iron, manganese, etc. All these metals are critical for diverse industries and human benefits. Salinity, temperature and pressure are the master factors, which control the physical and biochemical characteristics of the ocean waters.

Some recent studies reveal that particles of salt from the sea may play a role in cloud formation and subsequent rains, which nourishs life on the Earth. The salts make clouds turn into rain, by combining droplets into big drops. Scientists have actively suggested that the rain-generating giant nuclei, surrounded by sufficient moisture, are salt particles from the sea. When winds blow over the oceans they pick up this load of salt particles. Interestingly, ordinary sea winds carry anywhere between one and 12 kilograms of sea water per cubic kilometre of air, whilst storm winds bear 100 kg. These salts carried inland are responsible for rusting of our steel cupboards and loss of insulation in high tension cables of shore-based power generating units.

Lastly, life itself would not have evolved on this planet, if the sea were not salty! In short, life is believed to have originated in the 'primordial soup', with its rich source of carbon, nitrogen, etc and the permeating hydrogen. The dissociation of water by ultraviolet radiation and the gradual loss of hydrogen eventually led to oxidisation of the atmosphere, with subsequent formation of amino and nucleic acids. From there, the step to life is not very far.

It is beyond human imagination to build scenarios of what would have happened if the seas were not salty! We know not what creatures and plant life would then exist. Perhaps newer life-forms would have evolved. And man would have to do without the rich living and non-living resources which he has been harvesting from the sea. But man himself might not be there, or his biochemistry would have been far different.

B. PATEL

Dr. Patel is in charge of the Marine Radioecology Group in the Health Physics Division, Bhabha Atomic Research Centre, Bombay.

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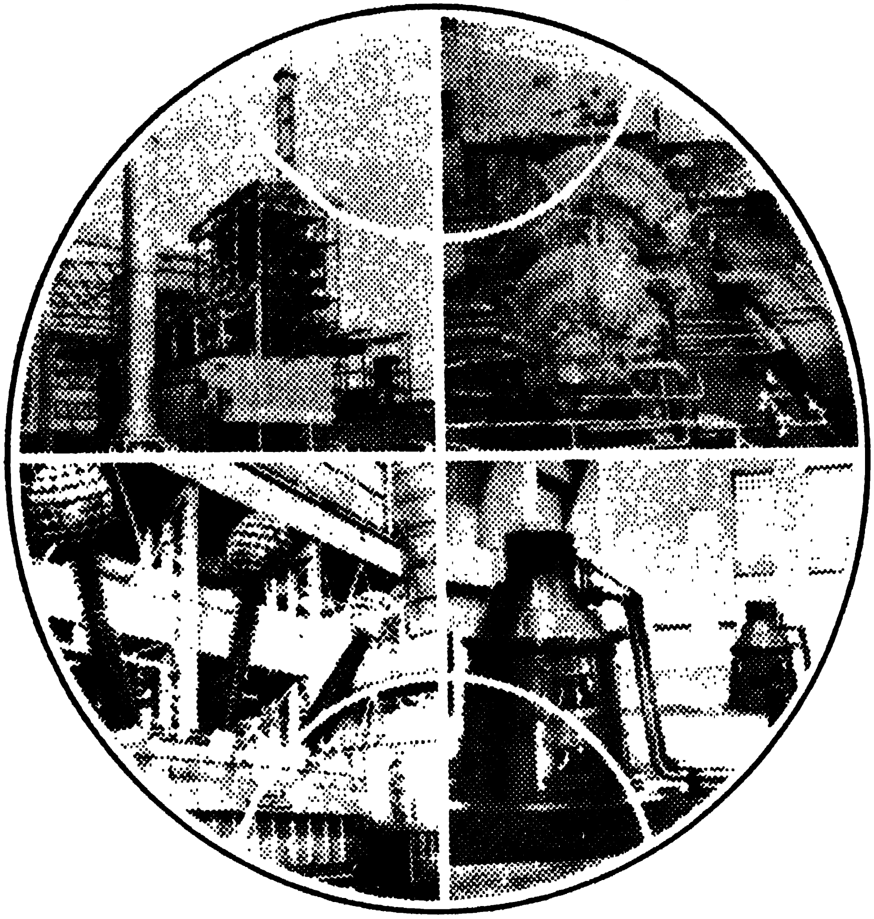

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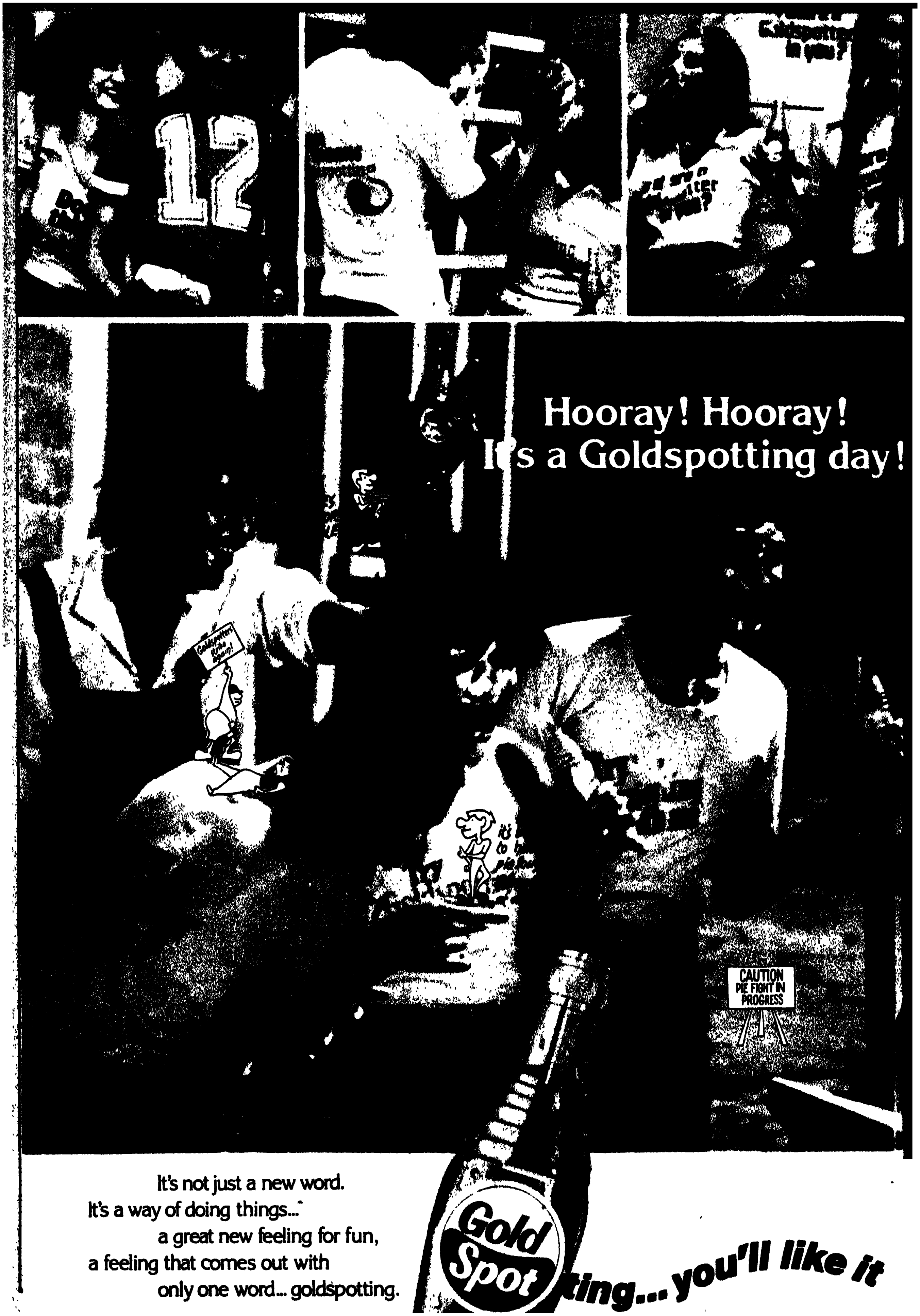

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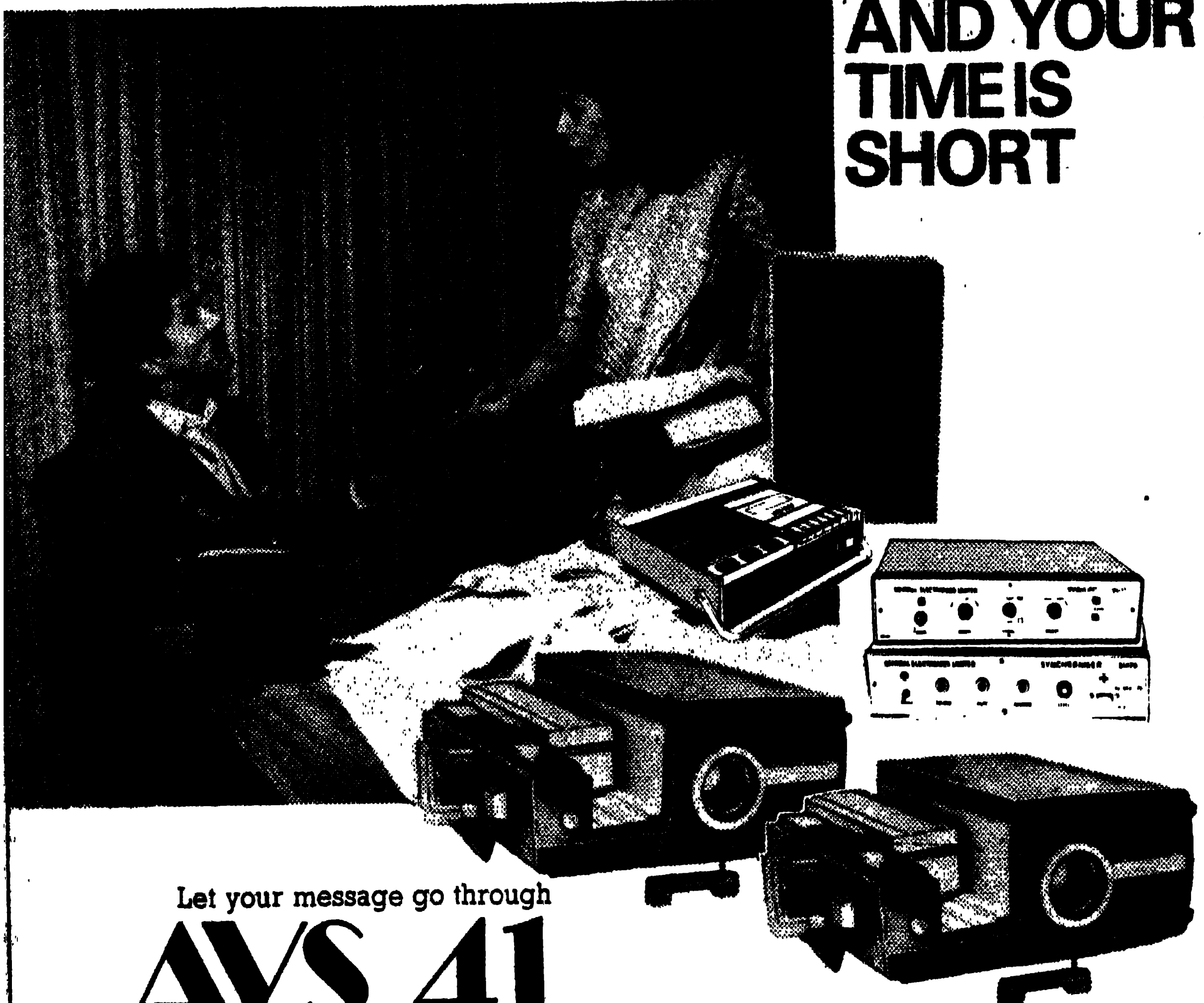

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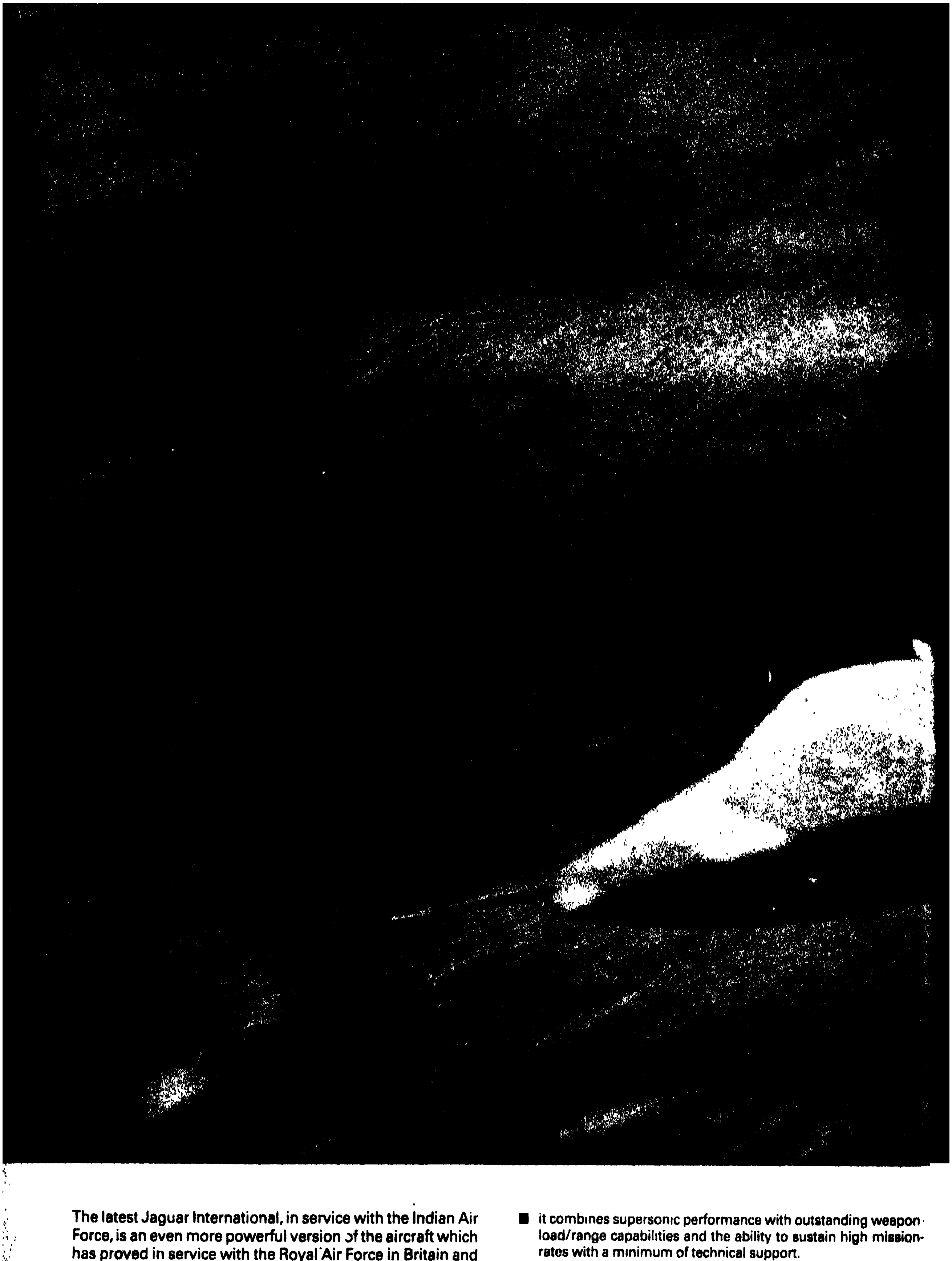

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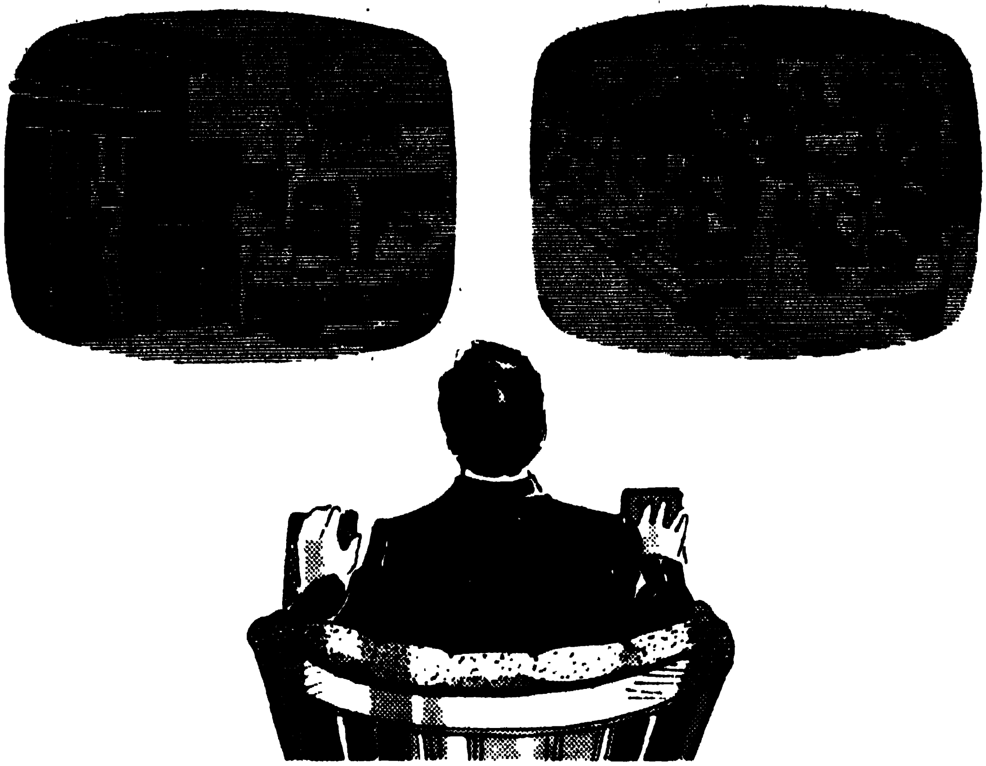

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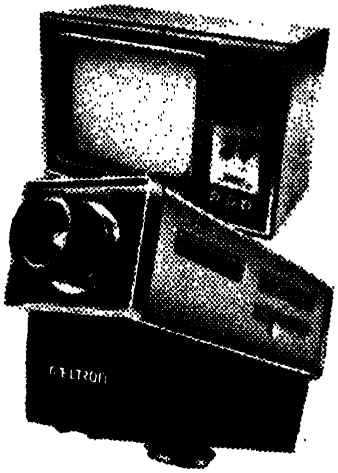

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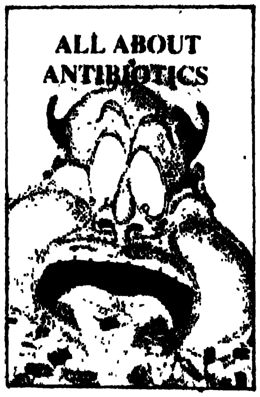

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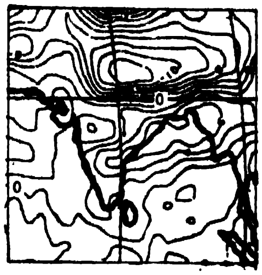

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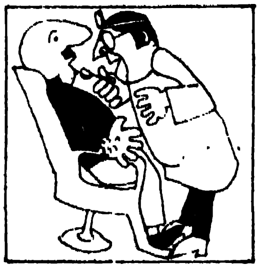

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ON BLAMING THE SCRIPTURES

READER T.M.S. Rao (Letters, June 1981) has seized upon a very small portion of my article (View points, April 1981) where I had said that unless our country can create scientists possessed with the spirit of a Galileo or a Darwin, our society will always remain a cesspool of superstition and backwardness. I had called for a defiance of the absurdities of our scriptures. This, Mr Rao interprets as an attack on religion. Nowhere in my article is there any attack on religion. On the contrary, I share Mr. Rao's view that religion is one's personal affair and a matter of individual faith and experience.

At the individual level, human beings, including scientists, have a variety of beliefs on not merely religious matters but on matters pertaining to politics, economics, international affairs, etc. The fact that one is a good scientist does not validate one's beliefs. However, the problems I had raised was one relating to the dominant ethos of a society. It is my view that our ancient society was a cesspool of superstition and backwardness. One does not see in it that passionate spirit of enquiry and questioning, so essential for science to flourish.

Mr. Rao mentions some unnamed German and French scientists who, he says, believe in the *Bible*. I would like to know whether these scientists think that Galileo was wrong in resisting the Inquisition. Also, what do these German and French scientists think about the importance of the Reformation and Renaissance in contributing to the spirit of free enquiry and to the emergence of humanism. And would one of Mr. Rao's French scientist friends approve of the massacre of St. Bartholomew, and the murders of the Guises, which took place in France in the name of counter reformation? Also, what does the *Quran*-reading Prof. Abdus Salaam think about the state of science and scientists in the Islamic Republic of Pakistan?

George Sudarshan and Oppenheimer might quote the *Bhagwadgita*, but would they contend that the laws of natural science are derived from the readings of the *Bhagwadgita*? I too read the *Bhagawadgita* and can even recite it and enjoy it. But when I come to consider secular areas like economics, politics and the sciences, I subject them to the investigative methodology of science which is quite distinctive from the methodology of metaphysics, theology and faith. That is why Albert Einstein in a letter to J.E. Switzer said that "development of western science is based on two great achievements: the invention of the formal logical system by the Greek philosophers and the discovery of the possibility to find out casual relationship with experiment (Renaissance)"

A very devout and religious man like Thomas Paine could not stomach the *Bible*. It's important to read his *Common Sense*. Our own scriptures need to be looked most absurd is *Manusmriti* with its views on women, "*sudras*", sacrifices at the time of *Shradh*, etc. At a *shradh*, etc. At a philosophical level, one has still to reconcile the various schools of philosophy to the nature and problem of change in our society. It was no less a person than the deeply religious Arobindo Ghosh who, when contemplating the state of our country, came to the following conclusion:

"If an ancient Indian of the time of the *Upanishad*, of the Buddha, or the later classical age were to be set down in modern India... he would see his race clinging to forms and shells and rags of the past and missing nine-tenths of its nobler meaning... he would be amazed by the extent of the mental poverty, the immobility, the static repetition, the cessation of science, the long sterility of art, the comparative feebleness of the creative intuition".

Prof. S. Radhakrishnan also has something similar to say: "We cannot live by ourselves in a world where aircraft and steamships, railways and telegraphs are linking all men together into a living whole. Our system of thought must act and react on the world progress. Stagnant systems like pools, breed obnoxious growths, while flowing rivers constantly renew their waters from fresh springs of inspiration... The problem facing Indian philosophy today is whether it is to be reduced to a cult, restricted in scope and with no application to the present facts, or whether it is to be made alive and real, so as to become what it should be, one of the great formative elements in human progress, by relating the immensely increased knowledge of modern science to the ancient ideals of India's philosophers".

Incidentally, in carrying out a public criticism, it is best to avoid value judgments by calling persons with whom one does not agree as "mediocre". Mr. Rao, should have displayed a more charitable disposition than he does and perhaps showed greater humility, he being so endowed with religious spirit.

P. N. HAKSAR

4/9 Shanti Niketan
New Delhi 411 021

ADULTERATION AND HEALTH FOR ALL

AN important aspect of Indian life where public health is imperilled is adulteration. Saroj S. Jha ("Health for all by 2000 AD", May 1981) has not mentioned this point in her otherwise comprehensive article. A serious threat to health is posed by hotels' where the food is far from wholesome. Even though there exists a machinery which is supposed to deal with adulteration, it is deliberately sluggish in its working. When prevention of disease is of primary importance, there should be greater awareness of this problem. As things stand, there is little concern for public health both on the part of the government and the hotel establishment. If we are to provide health to our populace by 2000 AD, then a process of changing the quality of edibles made available to the general public, and a consumer movement to patronise only things of standard quality, should start immediately.

G. ANANTHAKRISHNAN

'Pushkala'
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SIKHS AND SMOKING

I WOULD like to bring to your attention that a cartoon published in the July 1981 issue (Science Shapes Life, p. 19) is very objectionable to the Sikhs. The cartoon depicted a Sikh gentleman along with a Hindu gentleman standing before a cigarette shop. The Sikhs are non-smokers, smoking being against their religion. Hence the cartoon has hurt the sentiments of countless Sikhs.

K. S. CHEEMA

349, Baroda House
New Delhi

The turbaned character in the cartoon had his hands in his pockets and was not smoking—Ed.

PRIORITY FOR NITROGEN FIXATION

SYNTHETIC nitrogen fertilisers are expensive, and their production is a highly energy-consuming process (More Nitrogen For More Food, April 1981). In addition, the damage to the environment by these chemicals is also of concern. Hence biological nitrogen-fixation is gaining more and more importance, and researchers all over the world are improving the process. S.K. Apte (box, p. 23) has rightly pointed out that bacterial nitrogen-fixation is also a highly energy-intensive process. It may thus be said that the blue-green algae (cyanobacteria) are probably more efficient, as they perform both photosynthesis and nitrogen-fixation simultaneously.

Mention has to be made of the *Agrobacterium*. It is another bacterium, *Corynebacterium*, that produces fasciation in many plants; this is also a source of plasmids that may be used as vectors to transfer genes. The nif-genes of Rhizobium and Klebsiella are no doubt well known. But the cyanobacteria have also now been shown to contain plasmids and their nif-genes may be usilised for genetic engineering too. Indian workers have indicated the value of the blue-green algae in rice fields, particularly under Indian conditions. The genetic analysis of these cyanobacteria should be of great value in improving Indian agriculture. Analysis of plasmids, setting up gene banks for cosmid cloning, and the detailed study of genes for nitrogen-fixation should therefore be made as soon as possible. The Centre for Cell and Molecular Biology, Hyderabad, the proposed AMBO (Asian Molecular Biology Organisation), Tokyo and Bombay, should conduct work in this area. The Department of Science and Technology has already attached great priority to this. Re-introduction of cloned, wild-type or mutated nif-genes into the natural hosts and the study of the regulation of nitrogen-fixation and its manipulation in desired ways should bring great efficiency to the system and enough food for the growing population during the next century.

ARUN MISRA

Professor & Head
Botany Department
L.N. Mithila University
Darabhanga 864 004

ZOOPLANKTON

ON GOING through my article "Zooplankton" (July 1981), I found some errors

Below are the errors and the correct version:

Page 30, column 3, para 3: "For convenience, planktologists divide the zooplankton into three separate groups, depending on their size or morphology, the duration of their life cycle in the deep ocean, and their habitat or ecology." This should read: "The Zooplanktonic organisms can be grouped into various categories depending on different characters. They are mostly classified on the basis of (1) size or morphology, (2) duration of life cycle in the pelagic state, and (3) habitat or ecology."

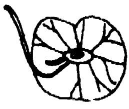
Page 30, column 3, para 4, line 11: "microplankton", should read "macroplankton."

Page 31, column 1, para 1, line 6: "The meroplankton are organisms which are planktonic during a part of their life cycle, such as eggs and larvae of fish, turtle, starfish, corals, clams, oysters, sponges, etc " should read: "The zooplanktonic organisms which are planktonic during a part of their life cycle, such as eggs and larvae of several nekton and benthos are called meroplankton."

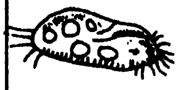
Page 31, column 1, para 2, line 7: "*Pseudodiaptemus*" should read "*pseudodiaptomus.*"

Page 31, column 2, para 1, line 1: "alyssopelagic" should read "abyssopelagic."

Page 33, column 3, para 1, line 1: and page 35, column 1, para 1, line 7: "*Euphausia superta*" should read "*Euphausia superba.*"



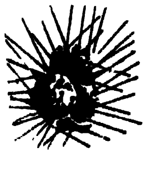
Noctiluca,



Amphisia

Tetraselmis

Ceratium



Globigerina

The caption for the sketch "Noctiluco" on p.30 should read "Noctiluca", "Diatom" for the sketch at the bottom on p. 32 should read "*Ceratium*", and sketches *Tetraselnus* and "Forminifera" on p. 34 should read *Tetraselmis* and *Amphisia*, respectively.

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LIQUID TORCH

THE hand-pumped compressed-air torch (Ideas & Inventions, July 1981) designed by K. Sheshadri of Madras seems a fine idea. However, I wish to make the following suggestions, which, I hope, if incorporated in the design would increase its efficiency: (1) Any liquid, such as water, kerosine, etc in the place of air would provide sufficient thrust on the turbine blades so as to increase the rpm of the turbine. (2) Provision should be made for the liquid to re-enter the tank through an outlet from the turbine chamber so that constant pressure can be maintained. (3) The walls of the turbine chamber should also have blades which web with the axil blades so that the liquid entering the turbine chamber, which however re-enters the liquid tank, will be forced out. (4) Care should be taken to see that the liquid tank is filled to three-fourths of its capacity. (5) The valve-tubes made use of in bicycles may be fixed at the inlet of the liquid tank.

SREENATH RAYASAM

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(Karnataka)

IF A SNAKE BITES YOU

POLYVALENT snake anti-venom serum or "Antivenine" is effective against the bites of all the four common land species of poisonous snakes found in India (Quiz, May 1981). Polyvalent antivenines are certainly safer than the "monovalent" ones, since the latter are highly specific in their action and can be administered only when one is sure of the snake which has bitten the victim.

For those involved in regular field work, it is advisable to carry at least two packs of antivenine for use in an emergency. For all we know, the field groups may never use it, but the packs may come handy to save a villager's life as they usually go bare-foot, and are thus more exposed. Antivenine (in lyophilised form) can be stored in the tropics for about five years without refrigeration. It is available from the Haffkine Biopharmaceutical Corporation, Bombay, on a doctor's prescription.

Since antivenines are highly specific in action and produced from horse serum, reaction (anaphylaxis) problems are likely to be encountered. Hence, the drug should be administered only on the advice of a qualified doctor.

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Cultural contours of iron in ancient India

THE ancient Greek historian Herodotus, in one of the earliest foreign accounts of the use of iron in India, unmistakably testified that the Indians in the Persian army used cane arrows tipped with iron. Ktesias, another Greek, spoke nostalgically of two swords made of Indian steel presented to him at the Persian court. Later, Quintus Curtis, a biographer of Alexander the Great, recorded that the gifts which Alexander received from Porus of Taxila (326 BC) included 100 'talents' of steel. Still later, in the early centuries of the Christian era, there is enough literary evidence to show that Indian iron and steel had attracted the attention of the West. Romans imported Indian steel to produce fancy cutlery and armours while Pliny refers to Indian swords of good quality steel.

Behind this qualitative excellence of Indian iron and steel lay centuries of metal craftsmanship, probably going back to the beginning of the first millenium BC. Radio-carbon datings indicate that iron appeared in India almost simultaneously in the north (Atrajikheda, Hastinapura in UP) and in the south (Hallur in Karnataka) by about 1,000 BC. This, however, poses an enigmatic problem—that of the origins and diffusion of iron technology in India.

Two major strands seem to characterise the spread of iron in India, one with a cultural component of what is known as the Painted Grey Ware of the so-called Aryan culture and the other of the Black-and-Red Ware pronouncedly of the Megalithic Culture (characterised by big stone monuments: from *megas*, big and *lithos*, stone), which had its sweep, by and large, in central and southern India from about the beginning of the first millenium BC to the second century AD. Indeed, the variety and quantity of iron objects unearthed in a number of archaeological sites are astonishing—adzes, daggers, chisels, hoes, spearheads, arrowheads, fish hooks, tongs of different types, rings, nails, knives, sickles, clamps, horse-bits, etc have all been found, many of them of no small size. More astonishing are the almost standardised forms of household, agricultural and warfare objects of iron found in appreciable numbers as "grave goods" in Megalithic burials. Their number is legion, dotting practically the whole of southern and central India. To this we shall return later.

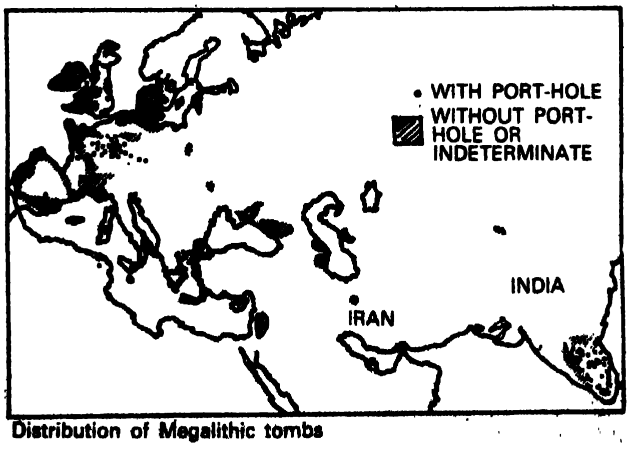
Apart from the Painted Grey Ware (*circa* 800 BC) and the later Megalithic Black-and-Red Ware, there was also another cultural component of iron in India—the Northern Black Polished Ware which had its origin in the eastern parts of India (Bihar) around 600 BC. In the next three to four centuries, ceramic assemblages overlapped, particularly the Painted Grey Ware and the Northern Black Polished Ware.. The latter had a little iron in it, inasmuch as some of these wares were dressed with haematite before firing and the black coating contained ferrous-oxide, according to some archaeological chemists.

If the two ceramic wares could then be taken as emergent elements along with iron, indicating the expansion of the Aryans and the assimilated cultures in the north and some parts of central India, what precise role could iron have played in such an expansion? Understandably, the iron implements enabled the people to clear jungles and seek new pastures. The use of iron ploughshares and other iron implements would surely have enabled them to intensify as well as diversify their agricultural operations, resulting in a sustained agricultural economy. Yet it would seem that, next to gold or silver, copper still occupied a pride of place in their socio-religious practices. The ironsmith, then as now, continued to be a member of the lowest strata of society whenever such a society came under the influence of the Aryan and the assimilated cultures in the first millenium BC. However, Buddhism with its new social values did not seem to have cast a disdainful look on iron or ironsmiths. The early Buddhist caves in eastern and western India needed the technical skills of the ironsmiths to chisel out the hard granite and Deccan trap. It is on record that an ironsmith even gifted a rock-cut path to a monastery in the Kanheri caves near Bombay.

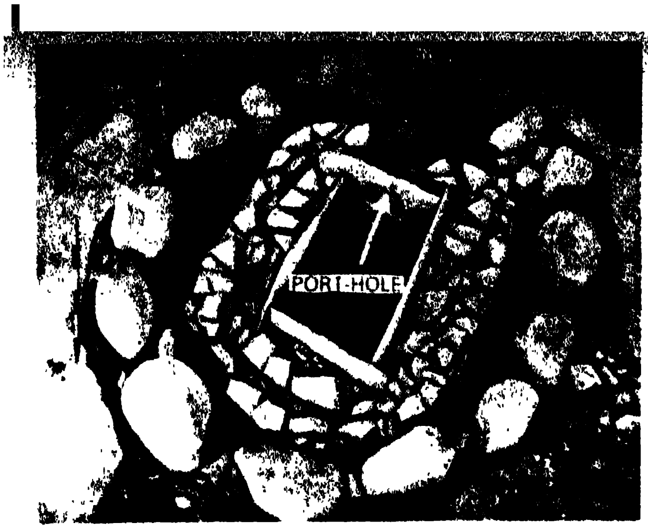
But who were these ironsmiths? Did they owe allegiance to the Vedic rites and rituals or did they have their own customs? Was the Vedic ancestor worship different from that of the community of ironsmiths? Even among some of the later Vedic people there was the practice of incarcerating the calcined bones in an urn under a mound, but without iron. From where, then, did the iron-mongers come? How did they spread? And was their spread unifocal?

As to these questions, for all of which satisfying answers may not be available on the basis of the extent archaeological data, we must turn our attention to the Megalithic Culture of India, characterised by a range of innumerable burials of different forms very often with rough and unhewn stones. The Megalithic Culture of India, probably dating from the beginning of the first millenium BC, extended its cultural spread up to about the first and second century AD and appears to have played a vital role in the diffusion of iron technology in India.

The Megalithic Culture also had a much wider, global ramification from about 3,000 BC to about the middle of the second millenium BC. Its cultural spread embraced the littoral countries of the Mediterranean and the Atlantic—Spain, Portugal, France, England, Germany, Scandinavia, North Africa, the Caucasus, Palestine, Iran and other Gulf countries of West Asia, and it later spread even further to the east. In its western spread, it generally displayed a development in the late Stone age or the Copper-Bronze age. Moreover, its spread was noticeable mostly in the coastal areas. Its Megalithic tombs, some of them with very large stones, are described to be of three types: the chamber tomb,



Distribution of Megalithic tombs



A typical port-hole cist at Brahmagiri, Karnataka

the single standing stone, and the grouped standing stones. Whatever the description, there is as yet no clear indication of the exact place of the origin or the structure of diffusion of this culture. Elliott Smith and Perry propose a series of waves starting from a single centre—a monocentric hyperdiffusionism. This, however, has not found favour with archaeologists and anthropologists. It is indeed difficult to speak of a Megalithic race in terms of physical anthropological connotation. Nevertheless, similarities and inter-relationships among the diverse Megalithic cultural spread indicate a rather hazy profile of the megaliths which might probably have originated in southern Europe from where it may have spread to West Asia, India and the Far East.

Origin and diffusion apart—opinions on them may differ—what could have been the motivation for the migratory movements of the Megalithic cultural people? Obviously they were looking for new places and new materials for an enriched living. It is not a mere coincidence that in certain parts of Europe, the Megalithic tombs overlap with metal-using economic or trading centres, or with metalliferrous regions. Although many of the tombs do not have metal objects in them, they seem to have stone copies of them according to Glyn Daniel of Cambridge, who adds, "... the passage-grave builders may have been in part responsible for the beginning of metal-working in Western Europe".

Viewed in this light, the Indian Megalithic Culture assumes a new dimension. Late entrants into the Indian sub-continent as they indeed were, the Megalithic people came to India when iron metallurgy was at least five to six centuries old elsewhere and when iron had already begun to establish itself as a useful metal. They, then seem to have found a congenial home in the central and southern parts of India with its plentiful iron ore, other minerals and workable deposits of stone.

Unlike their predecessors in Europe and West Asia, the Indian Megalithic people have left behind two important characteristic strands namely, the use of Black-and-Red ceramic throughout, and, more importantly, iron objects of almost standardised forms as "grave goods". Their predecessors elsewhere in Europe and West Asia did not appear to have used a single type of ceramic as a cultural component, nor were they associated with iron objects. This raises an interesting question—were the Indian Megalithic people knit together by common customs or culture, despite the wide variety of grave forms they employed? Perhaps they were, but this needs further investigation.

The archaeological evidence has revealed a variety of grave forms or types of Indian Megalithic monuments—cairn-circles, dolmonoid cists with or without port-holes, capstones lying flush with a heap of cairn, urn burials with capstone, single and multiple hood-stones, umbrella stones, sarcophagi or legged terracotta forms, menhirs, rock-cut caves and the like. All these monuments might belong to the general time-bracket ranging from about the beginning of the first millenium BC to the first two centuries AD. It would seem, as H. D. Sankalia observers, that the Megalithic monuments did not embrace the whole population; perhaps they were confined to a certain class or a particular group—chieftains, warriors, farming leaders and the like. In any case, not a few of the tomb-forms have their parallels in the European-West Asian Megalithic complex. The "grave goods" have a preponderance of iron objects, apart from others of gold and copper in small quantities. The presence of horse bits and the skeletons of horses in some graves indicates that the Megalithic people were horse-riders too. In addition, there is enough evidence to show that they were also agriculturists, built tanks and knew irrigation.

Yet, we are still in the dark in respect of the people themselves, their daily life, social organisation, economic activity and religious beliefs. Presumably, their belief was in the nature of ancestor worship. In the absence of any inscriptional evidence even in the later Megalithic burials—although script began to be used in India at least from the third century BC—it is rather difficult either to identify or to evaluate their other religious insights. It may be noted here that the Scythians or Sakas (of the first millenium BC and even earlier) were also known for their tombs and ancestor worship. The high esteem in which they held their ancestral tombs can be gauged by their encounter with the mighty Darius of Persia before whom they began to flee.

When taunted by Darius of their apparent cowardice, the Scythian king replied, "This is my way, Persian. I never fear men or fly from them ... I only follow my common code of life in peaceful years. If, however, you must needs to come to blows with us speedily, look you now, there are our fathers' tombs—seek them out and attempt to meddle with them—then you shall see whether or not we fight with you. Till you do this, be sure we shall not join battle unless it pleases us..."

The *Mahabharata* also refers to the Sakas and hence their sojourn in India is rather old. Iron was also known to them as early as 1,100 BC, yet we cannot say authentically whether they had anything to do with Megalithic culture in India. They were mostly confined to Western India from about 300 BC onwards and where practically no Megalithic tombs have come to light so far. Further, available archaeological data point to more than one wave of Megalithic people, who might have entered India either by sea or land. The principal focal point, if any, seems to have been the interior northern Karnataka of peninsular India.

Legged terracotta sarcophagus at Paltlavaram, Chingleput District, Tamil Nadu

To return to the Megalithic iron objects. Apart from their wide variety one would not fail to notice that many of them are indeed of a semi-macro scale, impressive and strong. For example, a long spear found in a Megalithic burial at Brahmagiri in Karnataka is more than two metres long. Moreover, many Indian iron objects have more than 95 per cent iron; some of them even having 99 per cent of it as can be seen from iron objects of Takal Ghat-Khapa, Mahurjhari and Naikund (Megalithic) near Nagpur in Central India.

At this stage we may perhaps reflect upon the famous Iron Pillar now standing unrusted near Delhi. The inscription on it suggests that it was erected by King Chandra early in the fifth century AD. When and where it was forged and shaped is still a moot point. The pillar, with a height of over seven metres and a weight of seven tonnes, has 99.72 per cent iron, 0.08 per cent carbon, 0.046 per cent silicon, 0.114 per cent of phosphorus, traces of sulphur and practically no manganese. As one foreigner has recorded a century ago, "It is not many years since the production of such a pillar would have been an impossibility in the largest foundries of the world, and even now there are comparatively few places where a similar mass of metal could be turned out." Among the reasons for the enduring quality of the pillar which has remained unrusted for over 1,500 years is a thin protective film of magnetic oxide that has been formed as a result of elaborate forging techniques. The rather high phosphorus and negligible sulphur or manganese content and dry weather conditions might be additional factors for its resistance to corrosion.

The pillar, representing the level of macro-technology of the time, is doubtless of high quality wrought iron like many Megalithic objects. Understandably then, the Megalithic ironsmiths had evolved the necessary technique to forge a large pillar, perhaps in terms of forging and bonding together viable iron segments of optimum size. Nor is it unlikely, that the descendants of the Megalithic ironsmiths, who might have been absorbed into the then emerging sub-caste spectrum of Indian society, had contributed their technical expertise, perhaps under royal patronage, to the forging of the famous historic metal-vestige of the world. This may seem, at present, an over-simplification. But it does emphasise the need to look at the still unsolved problem of the origin and production of the Iron Pillar.

Was the pillar forged somewhere in Central India where there is enough archaeological evidence of furnaces used for smelting and forging iron objects? Some interesting archaeological evidence of iron-smelting remains at Ujjain in Central India, according to N. R. Banerjee, includes enormous deposits of iron slag, unsmelted or partially smelted iron ore, lumps of calcite or aragonite and lime. The calcium compound could have been used as a flux and the extraction method obviously consisted of reducing iron ore using charcoal in small furnaces. As to the forging, the remains of a forge have also been unearthed at Ujjain. There is literary evidence to show that the iron workers of Avanti (an ancient kingdom, the capital of which was Ujjain, an important trading centre) had established a tradition of their own. The Tamil work *Manimekalai* nd *Perungadai* (early Christian era) refers to the iron workers of Avanti as being professionally the best in the country. It is indeed, interesting that King Chandra (Chandra Gupta II?) whose name appears in the inscription on the pillar had his suzerainty over Avanti where iron ores are available in the region of Indore and Mandassor not far from Ujjain. Was the Iron Pillar then forged near Ujjain? The question can finally be answered only after further investigation, including ore correlation studies.

The tribal practices of smelting iron in contemporary India may perhaps be seen as the possible methods employed for iron-smelting and forging in ancient times. Generally, the furnaces are tapering, vertical or cylindrical, about 75 to 90 cm high and 40 to 45 cm in diameter, made of select mud, plastered and hardened. They have three openings: the top one for introduction of the charcoal and iron ore, and the two at the base for maintaining the blast and letting out the slag and bloom.

In the past, the iron-makers might have used iron ore from almost any source in the vicinity. Iron ore occurs on a large scale in India, chiefly in the form of the oxides. Of these, large outcrops of haematite and magnetite of the dimensions of whole hills, which are being exploited for iron ores of high grade need special mention. Besides, iron is an important constituent of laterite, and in some varieties, the concentration of limonite or haematite is so high that the rock itself can be used for iron-smelting. In certain parts of India the main sources of iron ore are the laterite as well as the magnetite sands of rivers draining the geological trap, and these are still used by the itinerant ironsmiths still active in this field.

As to the production of steel, two processes appear to have been employed, namely, incorporating carbon into wrought or pure iron and decarburisation of cast iron to the desired carbon content of three to four per cent. One of the processes popular in South India consisted of filling small crucibles with pieces of wrought iron and four to five per cent by weight of firewood charcoal of good quality. Several such crucibles, sealed with clay, were placed upside down in a pit filled with fuel. The whole assemblage was subjected to intense heating using bellows. The molten liquid was then gradually cooled to obtain steel of good quality.

In conclusion, it may be emphasised that the impressive archaeological inventory of various iron objects in India, covering the first millenium BC and a few centuries later, have still to be scientifically evaluated. An anthropological study of the types of the people as well as their movement during this period will be of great value to a critical insight into the origin and diffusion of iron in India. A technological study of the macro objects, like the huge pillars at Delhi and Dhar (central India) as well as the iron beams of the temples of Puri and Konark (in Orissa), will enable us to assess scientifically the continuity of the iron-casting tradition in India over a long span of time.

B. V. SUBBARAYAPPA

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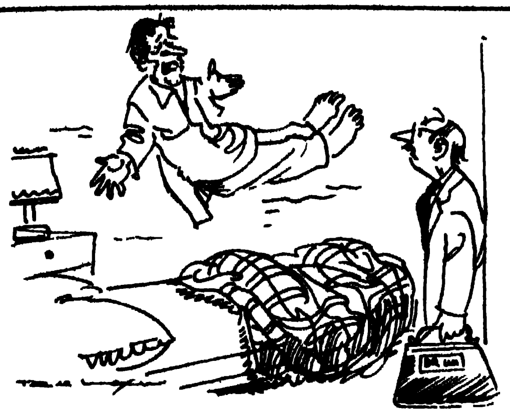
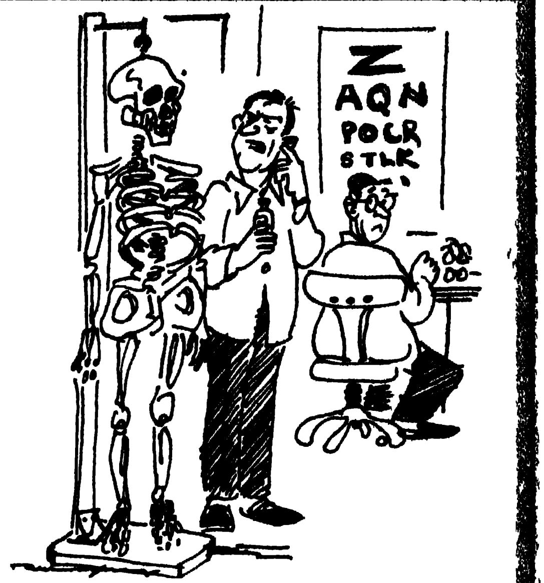
This World of Science!

By R. K. Laxman



"You came in time doctor You see I am losing weight rapidly!"



"Came back to ask you, sir—am I to put these eye drops once a day or twice?"

"This is all the fuel you will get per day—we have to use this tree till 2050 AD"

"Constantly I get this feeling that I am perfectly normal and that I am wasting my money coming here!"

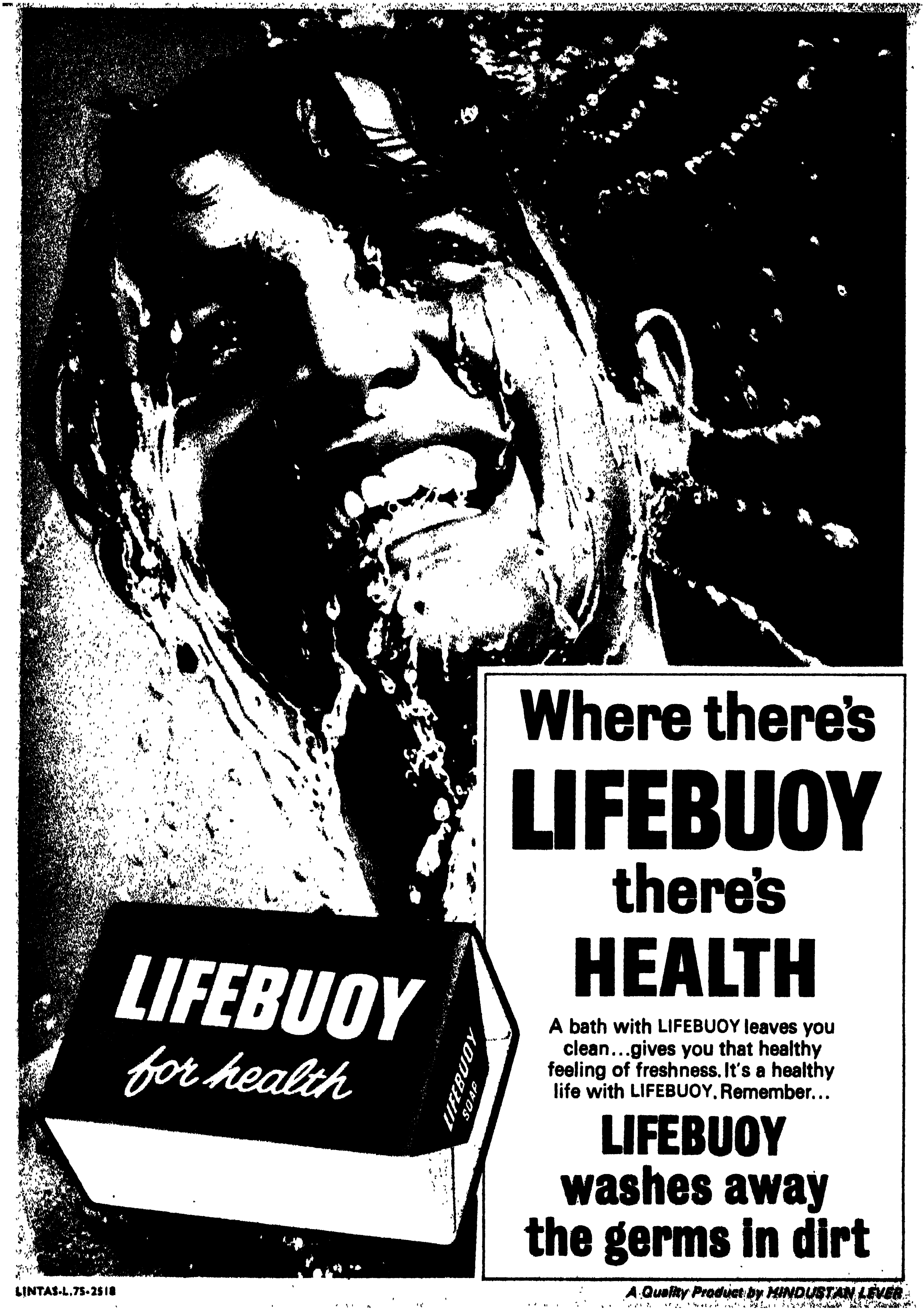
... and of Scientists

AN experiment to study the conversion of alcohol to energy was once carried out by Dr Johann Thudichum, the German-born British physician—best known for his research on brain chemistry during the third quarter of the last century — and his friends. This is how he graphically describes it "There were 33 in number including myself We drank from two o'clock in the afternoon till seven in the evening. 44 bottles of wine... The alcoholic content was an aggregate of 4000 grammes of absolute alcohol. All the urine passed from two o'clock till six the next morning was collected and distilled Only 10 grammes of alcohol was collected The rest was burned in the system "

THIS is how John Evelyn, the famous English diarist and secretary of the Royal Society, in 1672, referred to the pressure cooker invented by the French scientist Denys Papin. ". which was all dress'd, both fish and flesh in Monsieur Papin's Digesters by which the hardest bones of beefe itselfe and mutton, were made as soft as cheese, without water or other liquor, and with less than eight ounces of coals producing an incredible quantity of gravy; and for close of all a jelly made of the bones of beefe, the best for cleanness and good relish that I had ever seen or tasted ..but nothing exceeded the pigeons which tasted just as if bak'd in a pie . "

IN the twenties and the thirties of the current century, some 'new scientists' like Jeans, Eddington and Heisenberg led a campaign against determinism and claimed the powerful support of the Relativity theory This led the father of Relativity, Einstein, to declare: "Indeterminism is quite an illogical concept...If I say that the average life-span of such an atom is indetermined in the sense of not being caused, then I am talking nonsense."

By N. MUNSHI



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A bath with LIFEBUOY leaves you clean...gives you that healthy feeling of freshness. It's a healthy life with LIFEBUOY. Remember...

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DUST CLOUDS PROTECT LIFE FROM GALACTIC RADIATION HYSTERIA

Why have we Earthlings failed to catch on to any signal from any "extra-terrestrial" intelligent form of life in our galaxy? After all, scientists estimate that there are nearly a billion habitable planets in the Milky Way.

J. N. Clarke of the David Dunlop Observatory, University of Toronto, Canada, thinks that every 100 million years—give and take a few millions—enormous outbursts of radiation sweep the galactic slate clean of all life.

But then, how are we alive to talk about it? The answer it seems, are the dust clouds in the galaxy; they shelter a planet from the lethal radiation. The current estimates say it took three billion years for life to evolve on Earth; she must have managed to take shelter in dust clouds every time one of the 30 or 35 radiation bursts took place in her lifetime. Only the very few lucky planets must have survived this radiation onslaught. So, life may have been spread much more thinly than we expect.

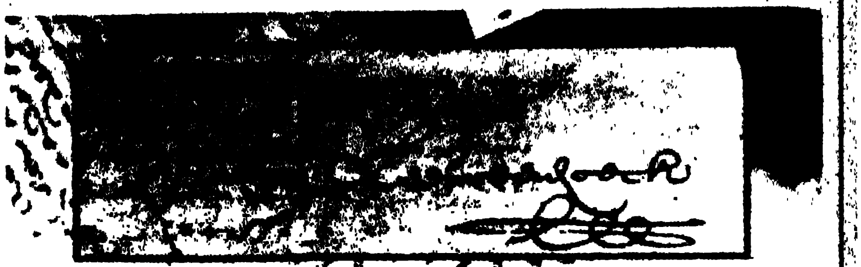
One out of 100 spiral galxies—our Milky Way is also a spiral galaxy—are Seyfert galaxies with very bright nuclei sending out lethal radiation to their surrounding stars. They can switch "on" and "off", being "on" about one per cent of the time, according to supporting evidence collected by M.E. Bailey, University of Sussex, and S. V. M. Clube, Royal Observatory, Edinburgh, both in the UK. So, in spite of our survival, the Milky Way might be going berserk with radiation every 100 million years.

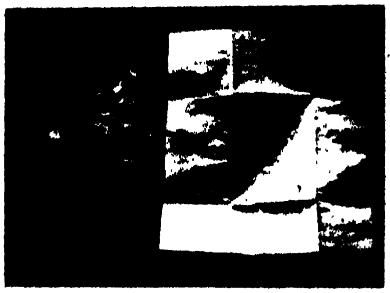
LEEUWENHOEK'S POSTHUMOUS REVENGE

Antony van Leeuwenhoek (1632-1723), the eccentric Dutchman who invented the microscope, peered through his instruments for decades and regaled contemporary London scientists with description after description of the most amazing minutae from sperms to bacteria. Experts, however, comment that his pioneering work was mostly crudely torn fragments—not the immaculate section one is now used to. Section-cutting, is it believed, did not start until as late as the middle of the nineteenth century.

The indomitable Dutchman has now stolen a march over his critics (*Nature*, 292, 407). Nine little envelopes containing some materials and attached to the final pages of three of his letters of 1674 have now been run to ground in the archives of the Royal Society, UK. One of the specimens, the white from the quill of a writing pen, has dwindled to a trace but the rest are intact and at least two are fine sections.

The fine sections are those of "Pit van vlier", or elder pith and "Kurk"—cork. The section of Leeuwenhoek's cork very clearly shows the boxed-in appearance of small rooms from which was derived the term "cell" in 1663. What is more important, the hand-cut sections of the "crude" Dutchman have suffered almost no structural damage and even today, after 307 years, they would be acceptable specimens in any of the laboratories of the world.





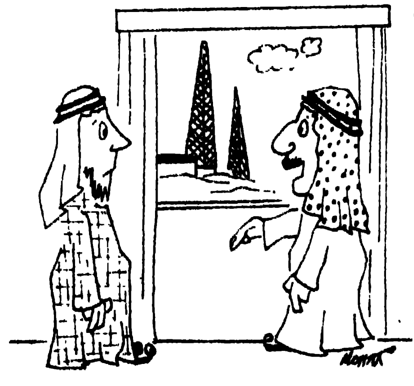
Pieces from the optic nerve of a cow cut in transverse sections, found attached to a letter dated 1 June 1674, signed by Leeuwenhoek. *Top*: Leeuwenhoek's specimen signature

AND NOW, ENERGY FROM BLACK HOLES!

Violate anything you will, but not the second law of thermodynamics. Older than most modern scientific theories and concepts, it has equably watched other laws and theories disintegrate and newer and newer ones replace them. And now it can boast of the ultimate victory, that over the cosmological black sheep that has already defied so many laws—"black holes".

Not only does the second law of thermodynamics hold true in a black hole—according to Jesse Unruh of the University of British Columbia, USA, speaking at a symposium in honour of the renowned physicist P.A.M. Dirac on his eightieth birthday—but it also makes it "possible" to "extract" energy from black holes.

But alternative energy buffs need not get too exicted. Unruh finds that a rocket moving through the gravitational field of a black hole and accelerating towards its surface will induce it to give up energy. All that is needed is a big enough push—an acceleration of 4 to 9 × $10^{[illegible]}$ metres per second per second!

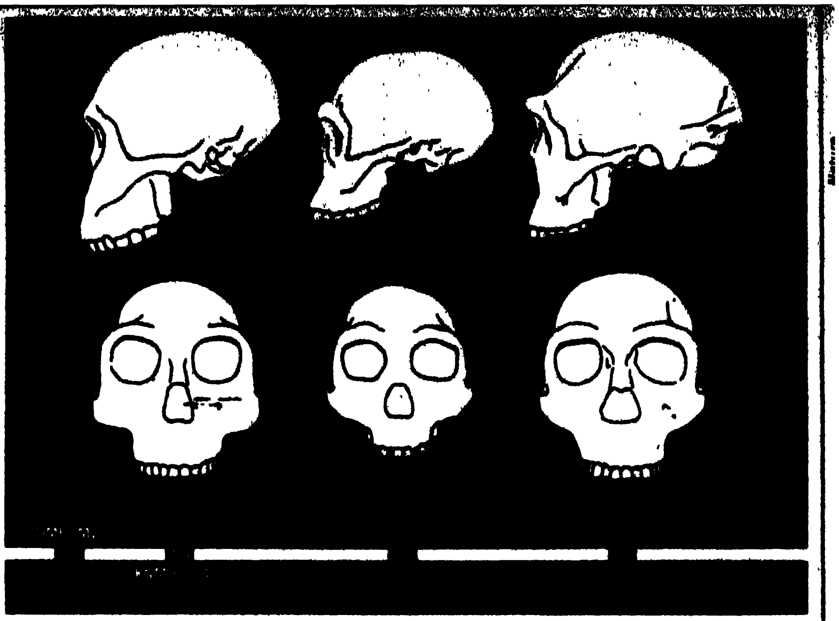


"In that case we better buy up as many black holes as we can, before the black gold dries up..."

WAS EVOLUTION GRADUAL OR IN JUMPS?

The concept of evolution has a theory that recently gained popularity. Known widely among the researchers as the theory of punctuated equilibrium, it maintains that humans and other species evolved over periods of rapid change interspersed with much longer static periods. In a recent issue of *Nature*, four anthropologists argue against this theory.

Their stand seems more conventional and they actually try "to confirm Darwin's and Huxley's views on evolution", to quote the principal author of the paper, John E. Cronin of Harvard. According to the authors, the proofs, whatever there may be of the theory of punctuated equilibrium stem from a bulk of erroneous assignment of dates. Take for instance, a skull specimen labeled KNM-ER 1470. It was at first



Was evolution gradual or in spasmodic leaps?

dated as being 2.6 million years old, but later re-dated as being only 1.8 million years old. This change of date reduced the minimum time of the species *Homo habilis* and took away a possible example of the *habilis* remaining static over a million years.

Cronin and his collaborators chart 44 morphological traits among four hominid species and three specimens they consider intermediary. For two of these, noting body weight and cranial capacity, which reflects brain size , they plotted graphs using estimated values for each of the four species. They could connect the points in a straight line. "The trend seems to show no jumps or discontinuities. Any impulse to draw a step diagram (which is the model of punctuated equilibrium) through the points should be resisted while the most parsimonious approach is to interpret the trends with a best-fit line", say Cronin and collaborators.

Further, these scientists regard the lifetimes of these hominid species as evidence for gradual evolutionary change. Each of the species, from *Australopithecus afarensis* to *Homo erectus*, lasted about 740,000 years. Punctuated evolution would have produced high variance in the lifetimes, because it can be assumed that each new species would have resulted from random evolution.

THE MYSTERY OF THE OLORGESAILIE MASSACRE

The scene is a circle about 15 metres in diameter at Olorgesailie, Kenya. Ninety bodies lie around. Each has its skull battered, probably by heavy stone axes (common in the area). They are the fossil remains of 90 giant gelada baboons (*Theropithecus oswaldi*) crowded into that small space nearly 400,000 to 700,000 years ago. And the murderers? Probably our hominid ancestors.

According to Pat Shipman of Johns Hopkins University who led the expedition that ferreted out the mystery, it is a unique incident; hominids have so far been known to have hunted antelopes, pigs, elephants, even hippopotamuses but not their fellow primates.

That the baboons could have been unfortunate victims of a natural disaster seems to be ruled out by the age and sex distribution of the baboons found here. At least today, in baboon groups the dominant male drives off the younger males as soon as they reach maturity so that the sex-ratio is tilted towards the females. By contrast the baboons found were all young, and the male-female ratio was one-to-one.

But then, why would our anccestors hunt baboons? The giant baboons were almost as large as the hominids, had large, sharp teeth and banded together into aggressive, highly protective groups. Easier game was surely available. Shipman and colleagues admit they have no "real explanation" but suggest a plausible—and pretty human—reason for the butchering. The hominids were perhaps engaged in seasonal or cermonial rites. Or perhaps the giant baboon's flesh was a favourite food—fitting enough for a ceremonial feast.

PASSING THE SCIENTIFIC BUCK

Research papers and projects are acquiring more and more coauthors and collaborators (SCIENCE TODAY, April 1981, p. 15)—a recent issue of *Physical Review Letters* (**46** 26) contains report coauthored by 63 researchers. A recent issue of *Nature* (**292, 5818**) contains two reports coauthored by 13 researchers. And more and more cases of fraud (SCIENCE TODAY, May 1981, p. 14) and even large-scale paper pirating (SCIENCE TODAY, July 1980, p. 14) are also coming to light. Who then is responsible for the results?

Custom and consensus has it that the senior investigator be held responsible. Marc S. Straus, the principal investigator of a Boston University medical research team which was discovered to have submitted falsified data to a multi-institutional clinical study in 1978, differs. Accepting full responsibility for patient care, he however disclaims it for the paper presented. Forced to resign his post after a complaint to the authorities by his team members, he has now filed a suit against colleagues for conspiracy, demanding damages to the tune of Rs. 200 million ($33 million) (*Science* **212** 4501, 1367).

A list of items that a principal investigator would have to look after is impressive—right from selection of personnel, account audits and their frequency to exhaustive checks on all aspects of the project from execution to preparing the final report. All the more so when he has many times provided more of inspiration and support than anything else.

The issue is bound to crop up everywhere with the explosion of papers, coauthors and collaborators. A US committee investigating such affairs is still at an impasse. The issue, like the Straus case, lies deadlocked between the "innocently wronged" seniors and the juniors falsifying data on orders from seniors and a "general anxiety" to continue the research. Responsibility, at the moment, is the main victim in this scientific buck-passing.

"It'd be most embarrassing if at least half the guests didn't agree to join our coauthorship...Happy birthday, Stetson!"

TYPE-A GO GETTING, TAKE CARE!

'Are you a "Type-A go-getter"? If so, remember this: you can't have your cake and eat it too. Well, if you haven't got the meaning of the phrase it's this. A Type-A go-getter is one you'd find anywhere—the people who can't bear to wait a little long for an elevator to come down, or for buses to arrive, or files to be cleared.

Psychologists have always suspected that such people usually sacrifice quality and creativity for sheer quantity. But now, a study by the (US) Society of Experimental Social Psychology shows that, at least among male experimental psychologists, the Type As turn out very good work.

Questionnaires were answered by 118 male members of the Society. The responses were studied against a standard index of citations. This index listed the number of times a certain psychologist was cited. It was assumed, and it is quite a fact, that better works get cited more often. The Type As, it seems, were cited most often.

But one old truth remains uchanged. The Type As are more prone to premature heart disease.

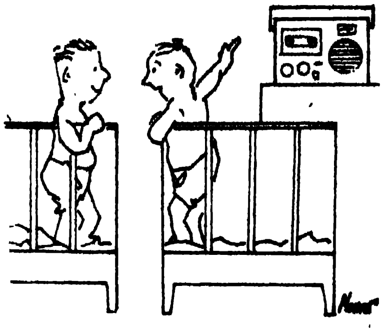
TAPES SOLVE PROBLEM OF CRYING BABIES

A decade ago, when it was realised that calm babies cried in response to the crying of other babies, psychologists described it as "emphatic distress". Now, an American behavioural scientist has found that the opposite is also true, if a baby hears it own cries.

Grace B. Martin of Savannah and Russell D. Clark of Florida State University (both in the USA) tested 36 boys and 34 girls in a local hospital nursery in Savannah. They played a four-minute tape of cries to both "calm" as well as "crying" babies (those babies who cried for more than three minutes prior to the test were labelled "crying", and those who were alert but cried for less than one minute, if they cried, were labeled "calm") and found that babies less than 35 hours old stop crying when they hear a tape-recording of their own cries, but cry with more enthusiasm when they hear another baby's cries. This was true even in the case of the calm infants who appeared to protest more when they heard the cries of another infant.

Could there be some form of baby language? Because when Martin and Clark made these infants listen to the cries of older children, or that of a distressed infant chimpanzee, there was practically no response from the newborns. This indicated that newborns could recognise the utterrances of other newborns like themselves, but not that of any other.

But parents who have crying children at home would find it a bad investment if they went and purchased tape-recorders just for this. Martin and Clark say this response vanishes as the child grows, and by six months after birth the tapes will be useless.



"I've stopped crying these days —that thing does the job for me!"

FETUS EYES MOVE, TOO

In the darkness of the womb the eyes of the fetus, so to speak, first wake up and then go into a deep sleep a few weeks before the fetus is born. Jason. C. Birnholtz of the Department of Radiology, Harvard Medical School, Boston, USA, recently monitored eye movements of more than 50 fetuses with the help of ultrasound and even found that definite types of such movements and their variations may be linked to dysmorphic—abnormally developed—brain structures (*Science* **213**, 679).

It is known that the vestibular nuclei, which are a necessary component for eye movements, are differentiated in a fetus by the time it is about 13 weeks old. Expectedly then, slow eye movements begin a couple of weeks later, around 16 weeks. By 23 weeks, eye movements analoguous to rapid eye movements, responsible for dreamy sleep in adults, begin and keep increasing in incidence till about 30 weeks.

Eye movements then fall off to a regular, quiet pattern characterisitic of deep sleep. The late phase inactivity of fetus eyes may be due to the development of inhibiting mechanisms. Hence the "deep sleep" pattern of eye movements just before the fetus is born—indicating possible formation of the mechanism that will help it sleep through infancy.

Eye movements have already been found to be a consistent indicator of the behavioural state of infants. Birnholtz went a step further. He also studied eight other fetuses with dysmorphic brain structures of widely different kinds and found them all to be quite different in pattern from the normal ones. Ultrasound may make it possible to recognise abnormal development of mental conditions before the fetus is born.

FOR BUSES, A 'STETHOSCOPE'.

It costs a lot of time and money when public buses go into the garage for a particularly long programme of testing and inspection, or of a defect hard to locate. A West German electronics firm has now introduced an electronic external testing system, which they claim reduces maintenance work and time off the road sharply. About 150 vehicle function can be checked automatically, including complicated faults, without having to strip down the assembly. Plug connectors link the test unit, that can be carried or moved about on a trolly to the bus.

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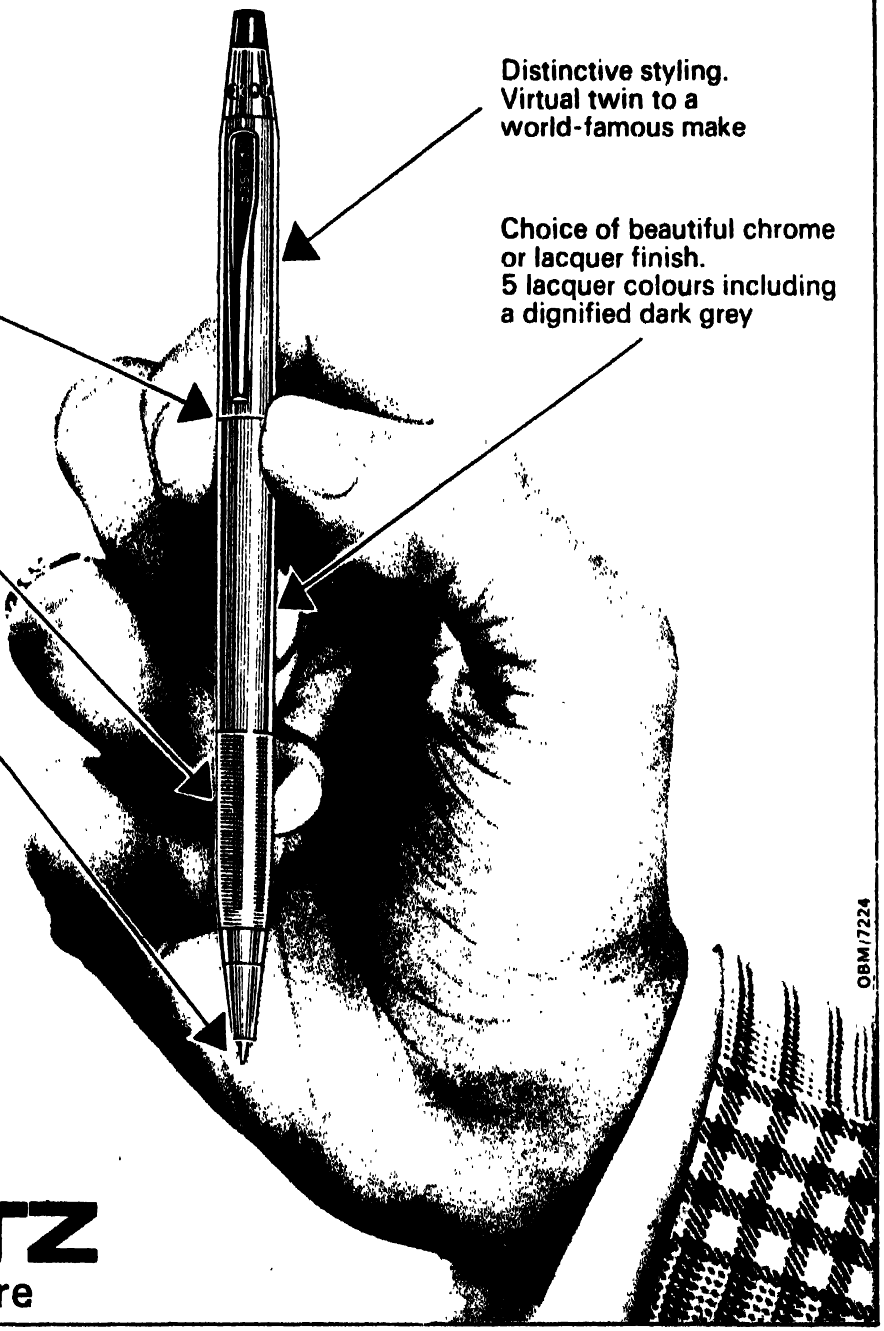

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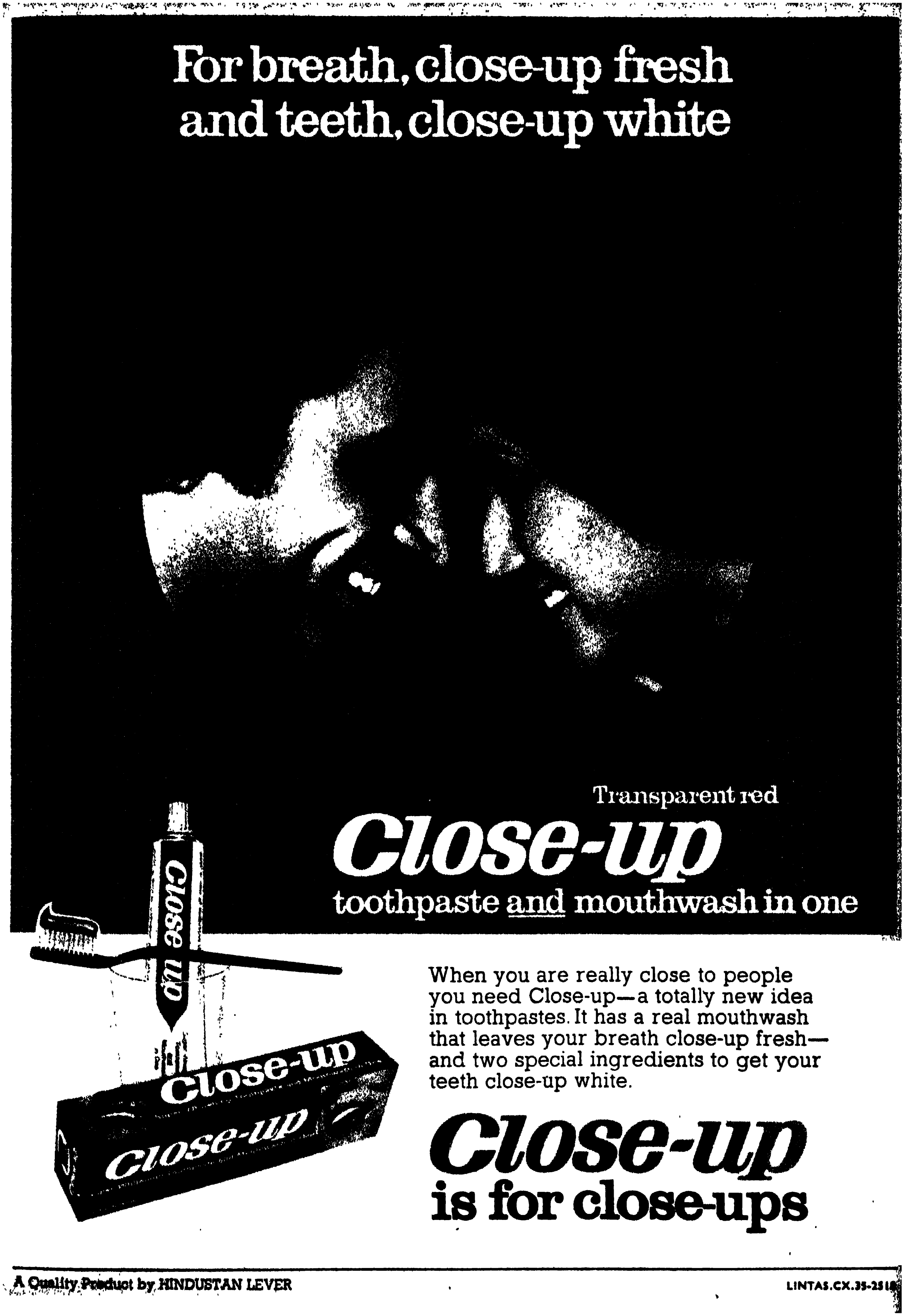

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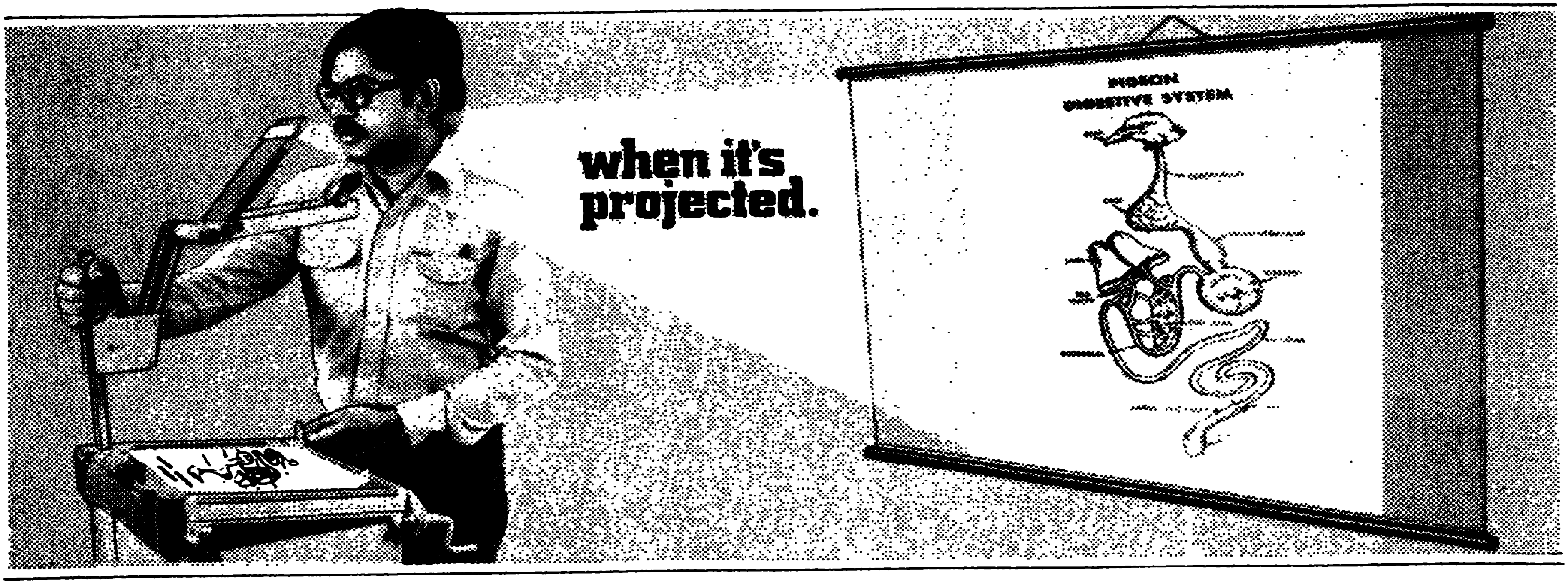
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Antibiotics

ANTIBIOTICS were man's first effective answer to a wide spectrum of diseases. These 'magic bullets' could destroy the disease-causing organisms without harming the surrounding host tissue. They succeeded in taming many intractable diseases (p. 20).

The success was, however, short-lived. Soon, the bacteria began to develop resistance, and many antibiotics no longer cure. In their fightback (p. 24), the bacteria have been helped by the widespread use, and misuse, of the antibiotics—a neat case of Catch-22. The indiscriminate use (p. 29) and promotion of antibiotics need to be curbed. Physicians and manufacturers and even patients and drug regulation agencies have all been responsible.

Yet, next to personal and public hygiene, antibiotics still remain the most effective weapon against infections. Last year, India produced bulk drugs worth Rs. 240 crores and formulations worth Rs. 1,200 crores; bulk drugs worth another Rs. 150 crores were imported. Despite the government drug policy to restrict them, private sector concerns, Indian as well as foreign, continue to be the major suppliers of these antibiotics. Most of them have shown little interest in research to combat the resistant bacteria and improve technologies to reduce drug prices. In fact, antibiotics provide a billion-dollar business to the multinational firms, and their hunger for profits has led them to exploit unsuspecting consumers, use unscrupulous means to promote their products, and even corrupt the medical profession. They dominate the antibiotic market and decide what antibiotics are to be used.

The new drug policy adopted by the government of India in 1978 requires all major foreign firms to have an R and D set-up in India and also offers incentives (like exemption from price control for a period of five years) for all indigenously developed bulk drugs. Though this has compelled many foreign drug companies to set up R and D establishments, these have mainly remained tax-saving and prestige-building strategies. The R and D rarely goes beyond preliminary screening of different microbial strains from Indian soils for antibiotics production, and shipment of promising ones to parent companies abroad. Products and technologies developed on these strains will then be sold back to us.

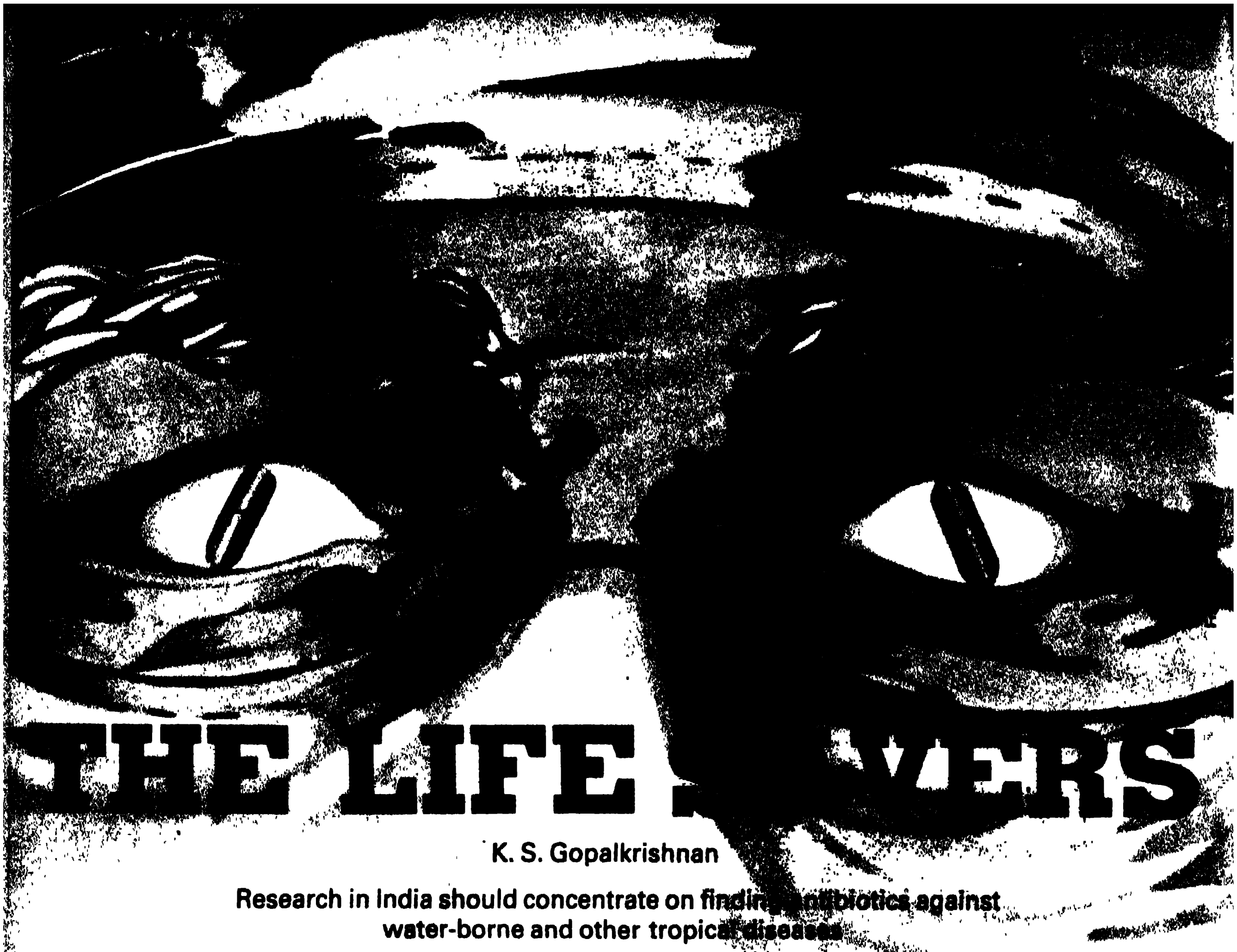
Perhaps this was foreseen by the government. The terms of reference of the Hathi Committee (set up in 1974 to inquire into the drug industry in India, its report formed the basis of the new drug policy of 1978) included recommending "measures necessary to ensure that the public sector attains a leadership role in the manufacture of basic drugs and formulations, and in R and D". The drug policy stated: "In order to reduce dependence on import of technology in general, urgent steps will be taken to equip the public sector units as also the national laboratories with such R and D and pilot plant equipment, as may be necessary. Public sector units will also ensure that they have a strong design and engineering component in their R and D structure, so that chemical processes that may be developed, be indigenously tested and scaled up with the necessary complement of competent indigenous design and engineering skill." It further said: "Public sector units will maintain the closest liaison with the R and D units of national laboratories, state institutions/other educational institutions... Highest priority will be accorded to centrally directed research aimed at discovery of newer drugs for treatment of tropical diseases, anti-malarials, anti-filarials, anthelmintics and anti-leprotics."

The R and D establishments of the Indian Drugs and Pharmaceuticals Ltd (IDPL) and the Hindustan Antibiotics Ltd (HAL), the two public sector drug manufacturing units, are not strong enough to meet these objectives. They have mostly been dependent on imported technology and imported strains for their antibiotics production, which is still only a small fraction of the total production in the country. They have not been able to improve sufficiently the imported technology and strains to keep pace with developments elsewhere. And they will probably continue to import improved strains for the same drugs, or use obsolete and expensive technologies.

Meanwhile, rapid developments of newer technologies in microbiology, such as gene cloning, is revolutionising microbial industries in the advanced countries. Cloned genes can improve the yields of specific products and bring down their prices. Newer strains are soon going to replace the old ones in the manufacture of most drugs. We must strengthen our R and D and set up close liaison between universities, national laboratories and the drug manufacturing units, if self-reliance in drug technology and making drugs available at reasonable prices is to be a reality. Without developing this alternative, there can be no question of effectively protecting the public from harmful and obsolete drugs being dumped by the multinationals and their subsidiaries with the connivance of uninformed or unscrupulous doctors and pharmacists.

B. S. MAHAJAN

Dr. (Mrs.) Mahajan is on the editorial staff of SCIENCE TODAY.



THE LIFE [illegible]VERS

K. S. Gopalkrishnan

Research in India should concentrate on finding antibiotics against water-borne and other tropical diseases

THE FIRST announcement of penicillin by H. W. Florey and his colleagues in 1940 may be considered the beginning of the antibiotics era. Since then, many-splendoured fallouts and fantastic developments are in progress. Little did anyone realise at the time that penicillin, besides providing a firstline remedy for infections resistant to sulphanamides (gram-positive infections), was also a secondline defence against those fully susceptible to them. But for the advent of the antibiotics at a most crucial time, all the benefits of Domagk's sulpha discovery might well have been lost. Very rightly, the antibiotics earned the name "life-saving drugs". Few developments in the history of medicine have had such profound and far-reaching effects on human life and society as the power to control microbial infections.

P. Vuillemin first coined the word antibiosis in 1889 to define antagonism between living organisms, but the word antibiotic was first used by S. A. Waksman in 1942. He defined an antibiotic as a substance produced by microorganisms antagonistic to the growth of others in very low concentrations.

Antibiotics are natural organic compounds produced by microorganisms. Their marked and selective anti-bacterial activity and low toxicity have made their use possible in the treatment of many epidemiological diseases. In nature, they occur as groups of related compounds in related microorganisms. Some antibiotics, however, have been produced by unrelated microorganisms, indicating that these essentially secondary and terminal metabolites are of little significance to the basic biosynthetic pathways of the organisms. These metabolites apparently are not essential to the life of the cell.

Many infectious diseases are controlled by antibiotic therapy—bacterial pneumonia, meningitis, tuberculosis, typhoid fever and certain veneral diseases to name only a few. The average duration of these diseases has decreased and even the severity of many infectious diseases has diminished. The marked fall in mortality rates with the introduction of antibiotics offer striking evidence of the effectiveness of antibiotics. Factors like better sanitation and nutrition, and immunisation programmes have also contributed to the low mortality rates.

The discovery of penicillin at St. Mary's Hospital, London, UK, by A. Fleming in 1928, after a plate seeded with staphylococci and put aside on the laboratory bench had been accidentally contaminated with *Penicillium notatum*, is now well known. Fleming thought that penicillin secreted by the colony of the mould had lysed (burst open) mature colonies of staphylococci. But this could not have been so, since penicillin lyses growing but not resting organisms. It appears that after contamination with the *Penicillum* the temperature in the room was such that the mould grew and began to produce penicillin without rapid growth of the bacteria. Warm weather accelerated the growth of the staphylococci, which underwent lysis in the vicinity of the mould.

Twelve years after the discovery came the demonstration of the chemotherapeutic powers of penicillin, first in mice and then in men. Florey and E. Chain, working in Oxford, England, decisively proved that penicillin was non-toxic in man and acted as an extremely active anti-bacterial agent. Impressive clinical evidence followed, which confirmed its high specific antibiotic activity and the low toxicity.

Penicillin was thus the first antibiotic to be used therapeutically; in many ways, it is still the best. Some of its properties are indeed so unique that it is nothing short of a miracle that so amazing a substance should have been the first of its kind to be discovered. And it was fortuitous that penicillin was discovered at the time when the sulpha group of drugs were losing their effect in therapy, and drug scientists all over the world were looking for substitutes.

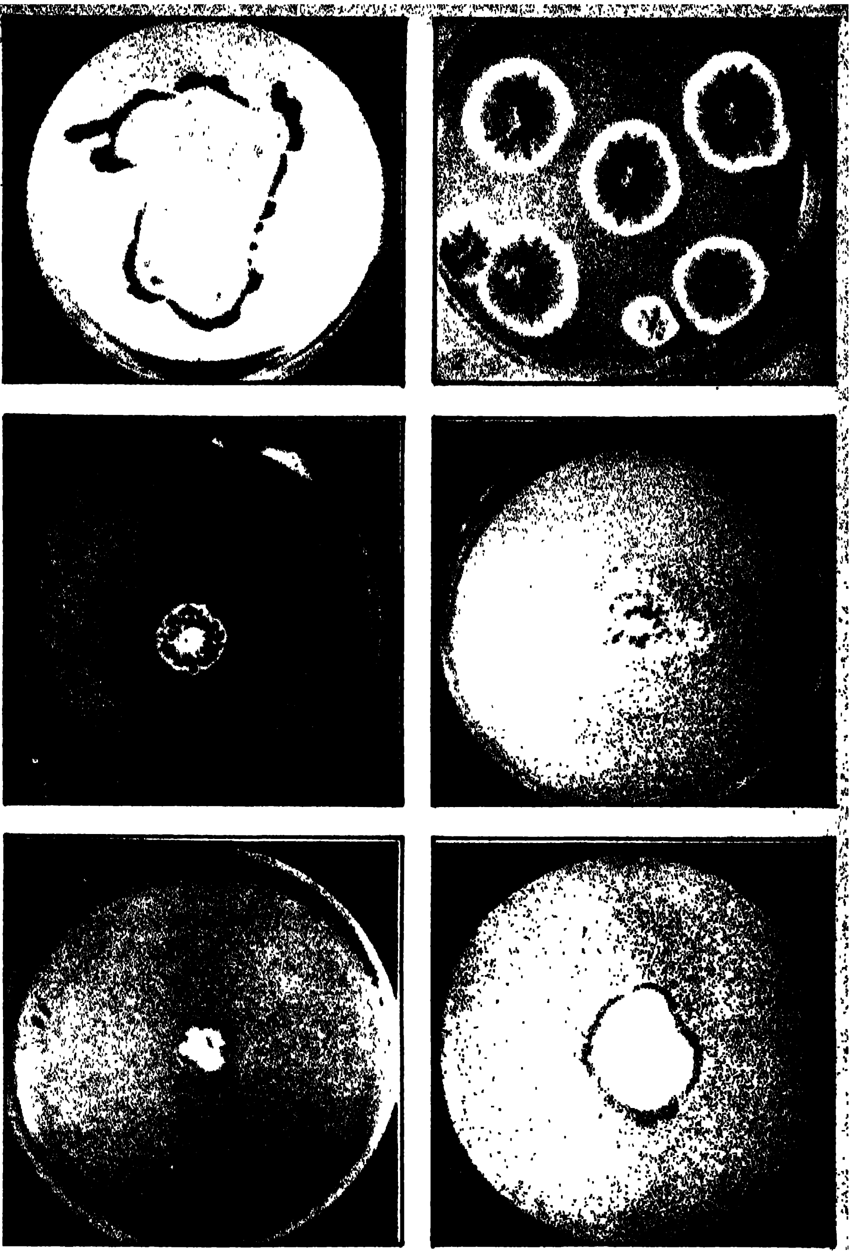
Equally fascinating is the discovery of streptomycin, the first antitubercular antibiotic. Prof. Waksman's department of soil microbiology in Rutgers University, USA, would have closed down in 1939 because of lack of funds, but for the timely intervention of some far-sighted scientists who happened to have some say in the university affairs. Within three years, Waksman discovered streptomycin for which he won the Nobel Prize in 1952.

With the discovery of penicillin and its establishment as a safe and useful antibiotic, laboratories and industries all over the world looked for microorganisms which would produce useful substances. Out of such systematic screening of soils flowed many discoveries, including the principal antibiotics currently in use. In the last 40 years, well over 3,000 antibiotics have been discovered. But very few of them have been found to have the right combination of properties—high activity against the invading organism, low toxicity in mammals and physical and metabolic stability to justify their use in man.

Range of antibiotic action

Antibiotics or antimicrobial drugs kill or inhibit the growth of the bacteria in many ways. They must, therefore, possess the capacity to inhibit or destroy the pathogen (disease-causing organism or substance) without injuring the host cell. Bacteriostatic antibiotics inhibit bacterial reproduction but do not kill the bacteria. So when the antibiotic is removed, the bacteria start to grow again. Bactericidal antibiotics are lethal, and kill microorganisms directly. Broad-spectrum antibiotics, like tetracyclines and chloramphenicol, are effective against a large number of species and unrelated microorganisms like bacteria, rickettsiae, bedsonia and viruses. Narrow-spectrum specific antibiotics (penicillin, streptomycin, etc) are effective against only a few types of bacteria.

The essential functions inhibited by antibiotics vary. Certain antibiotics interfere with bacterial cell-wall synthesis; these include penicillins, cephalosporins, vancomycin and



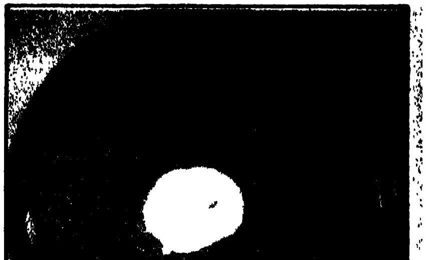


Fig 1: Colony morphology of some antibiotic-producing microorganisms:

(1) *Streptomyces californicus*—viomycin, (2) *Penicillium*—penicillin, (3) *Streptomyces fradiae* — neomycin; (4) *Streptomyces rimosus*—oxytetracycline; (5) *Streptomyces aureofaciens*—chlortetracycline; (6) *Streptomyces griseus* — streptomycin, and (7) *Bacillus polymyxa*—polymyxin

Fig 2: Laboratory fermentors

cycloserine. Tetracyclines, chloramphenicol, erythromycin, lincomycin, novobiocin, streptomycin, gentamicin, kanamycin and neomycin kill the bacteria by inhibiting protein synthesis. Polymyxin, colistin, nystatin, amphotercin B and hamycin affect the cell membranes of bacteria, yeasts, and fungi. Griseofulvin affects nucleic acid metabolism in certain fungi and hence is an effective antifungal agent. The mode of action, is, therefore, against some basic cell function like protein, RNA or DNA synthesis.

How are antibiotics produced commerically? The key step is the fermentation process. Strains of the microorganisms selected after elaborate screening (Fig. 3) from randomly isolated pure cultures are inoculated into a nutrient medium in large bioreactors. Incubation follows for varying periods. The growth and productivity of microorganisms is greatly helped by optimised nutrient-medium, temperature, aeration and agitation. Different strains of a microbial species may differ greatly in antibiotic productivity. Variations in cultural conditions also affect antibiotic productivity by a strain.

Many new and useful antibiotics are produced today by chemical modifications of the original parent antibiotic obtained by fermentation. These derivatives possess many useful properties, not possessed by the parent compound. For example, many chemically modified penicillins are effective against those bacteria which have become resistant to the parent penicillin molecule. Still others are effective against a wider variety of microorganisms; some others exhibit better absorption by body tissues. Chloramphenicol, which is widely used, is produced by chemical synthesis and not by fermentation.

Once an antibiotic-producing strain is isolated and characterised, the microbiologist's interest is directed to improving or increasing its ability, that is, selecting a better producer of antibiotics. Excellent results have been obtained with practically all the industrially important antibiotics. To quote only a few examples of such genetic increases: penicillin levels from its original of about two units is now whispered to be about sixty to eighty thousand units per millilitre; streptomycin levels are now about 35,000 units per ml, chlortetracycline 25,000 units per ml, and oxytetracycline about 35,000 units per ml from their original levels of 10 to 25 units per ml.

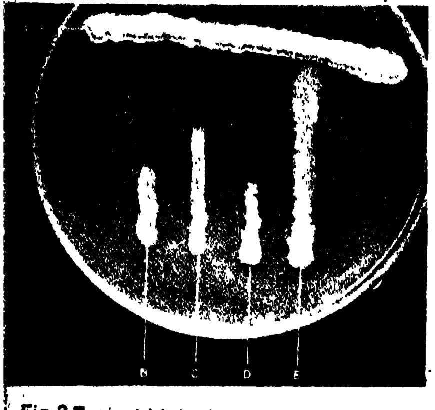


Fig 3.Typical biological assay for antibiotic production. In the figure A is the antibiotic producer and B, C, D and E are test microbes

It is easy to see the far-reaching effect such an improvement has on the price of the drug. Similar developments have made it possible to bring down the prices of other life-saving drugs, and make them easily available. Although initially the USA was the pioneer in this industry, the European countries soon followed and established antibiotic manufacturing companies. Japan followed suit in the late 1940s. The first Indian unit in the public sector went into production in 1954-55 (see page 19). Some of these developments led to the rapid establishment of a flourishing multi-million dollar multinational industry. This manufacturing activity spawned prodigious research in microbiology and chemical engineering to establish a whole new branch of engineering science—biochemical engineering. It also encouraged phenomenal developments in research into cell biology and microbial genetics.

Today, the thrust is towards researches on semi-synthetic derivatives, reassessment and novel methods of screening microorganisms and sampling unusual ecological habitats for isolating new ones. Also, a better genetic understanding of the antibiotic-producing organisms has already made a significant impact on production of several antibiotics.

The rate of discovery of clinically useful new drugs from microbial sources dropped sharply in the late fifties, while partial synthesis of new,

Struct[illegible]

[illegible] Helenine—an antibiotic from P. funiculosum, which had grown on a photograph of the discoverer's wife. The antibiotic bacitracin was named after Tracy, the first patient to whom it was administered. However, the later antibiotics were systematically named either on the basis of the organism which produced them, or the chemical nature of the antibiotics (if this is known) or their major antibiotic activity.

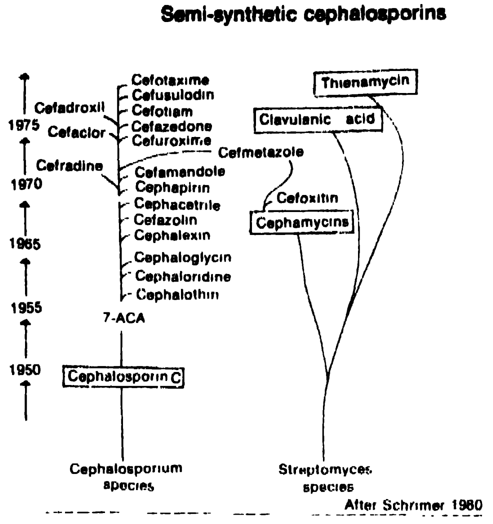
The chemical structure of antibiotics varies widely. This can be considered at three levels: the functional groups, the sub-units, and the total molecule. The functional groups would include hydroxyl, carbonyl, amino, imino, sulphydryl, nitro, and other groups. The sub-units include amino acids, peptides, hydroxy acids and derivatives. The total character of the antibiotic molecule depends on the type of linkages, the location of sub-units and the functional groups present. Such a structure naturally gives rise to problems of a rational chemical classification. Today, the structure of many antibiotic compounds is known because of significant advances in instrumentation, chromatography and separation and identification techniques of even minute quantities.

The classification of antibiotics is usually based on: (1) taxonomy of the producing microorganisms, (2) metabolic pathways of bio-synthesis and nature of the precursors of the antibiotics, (3) chemical structure, and (4) activity spectrum and mode of action.

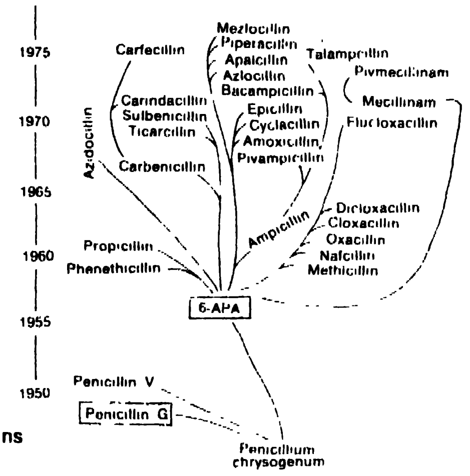
[illegible] a chemical classification might be the least equivocal. The chemical structure of at least 60 per cent of the antibiotics described are known, and detailed structures of all the important commercial antibiotics are also fully known, both by analysis and total synthesis. Therefore a molecular classification of the antibiotics might be considered as follows:

1. Penicillin and related antibiotics have a beta lactam ring. Examples: Natural penicillins, semi synthetic penicillins and cephalosporins.
2. Aminoglycoside antibiotics, represented by streptomycin, neomycin and amikacin, have amino sugars in a glycosidic linkage.
3. The macrolides, like erythromycin and oleandomycin, have a macrocyclic lactone.
4. The tetracyclines have a polycyclic naphthone carboxide structure.
5. Chloramphenicol is a class by itself—a nitrobenzene derivative of dichloracetic acid.
6. Peptide antibiotics are large molecules which have peptide-linked amino acids of both D and L forms.
7. Antifungal antibiotics, both polyenes and non-polyenes.
8. Unclassified, varied structures like cycloserine, fusidic acid, novobiocin, etc.
9. Ansamacrolides derived from naphtho and benzoquinone nuclei, like streptovaricins and rifamycins.
10. Anthracycline antibiotics, like adriamycin, duanomycin etc.

K. S. G.


Semi-synthetic cephalosporins

After Schrimer 1980


Semi-synthetic penicillins

derived antibiotics (notably from beta-lactams and tetracyclines) with improved biological properties, increased. Systematic examination of previously little-known genera of microbes, especially of the actinomycetes group, for antibiotics, the use of the new culturing and screening techniques and testing for more diverse type of biological activities will probably provide significant new discoveries. Of the groups of antibiotics whose derivatives have been prepared, beta-lactams have proved to be the most useful and prolific. Although the original hope of tailor-made antibiotics has not yet been fulfilled, a great deal has been done both with penicillin and cephalosporin.

Current research centres on the two important antibiotics groups—penicillins and cephalosporins. Both are beta-lactam antibiotics and have similar nuclei, namely 6-aminopenicillanic acid (6APA) and 7 aminocephalosporanic acid (7ACA), respectively (see box on p.31). While the derivatives of beta-lactams, tetracyclines, aminoglycosides (like gentamycin), and rifamycin have yielded useful derivatives, those of chloramphenicol have never been better than the parent substance.

The problems in discovering new antibiotics is not so much the actual finding of some antibiotic property of microorganism but the large expenses involved in development and testing. It is estimated that it costs approximately nine to ten crores of rupees and takes a period of ten years before a newly discovered drug can be marketed. This is the reason why most of the current research in antibiotics is restricted to producing derivatives of known compounds, except in areas of virus infections and cancer where known safe therapeutic substances are not yet available. Several Acts and rules govern the manufacture and sale of drugs.

The total value of antibiotics sold all over the world is estimated to be about 5,000 million dollars (in 1979). Of this, the beta-lactam group alone has a 20 per cent share and semi-synthetic antibiotics from a large portion of this.

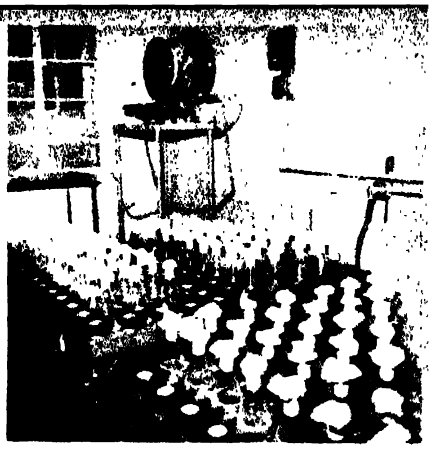
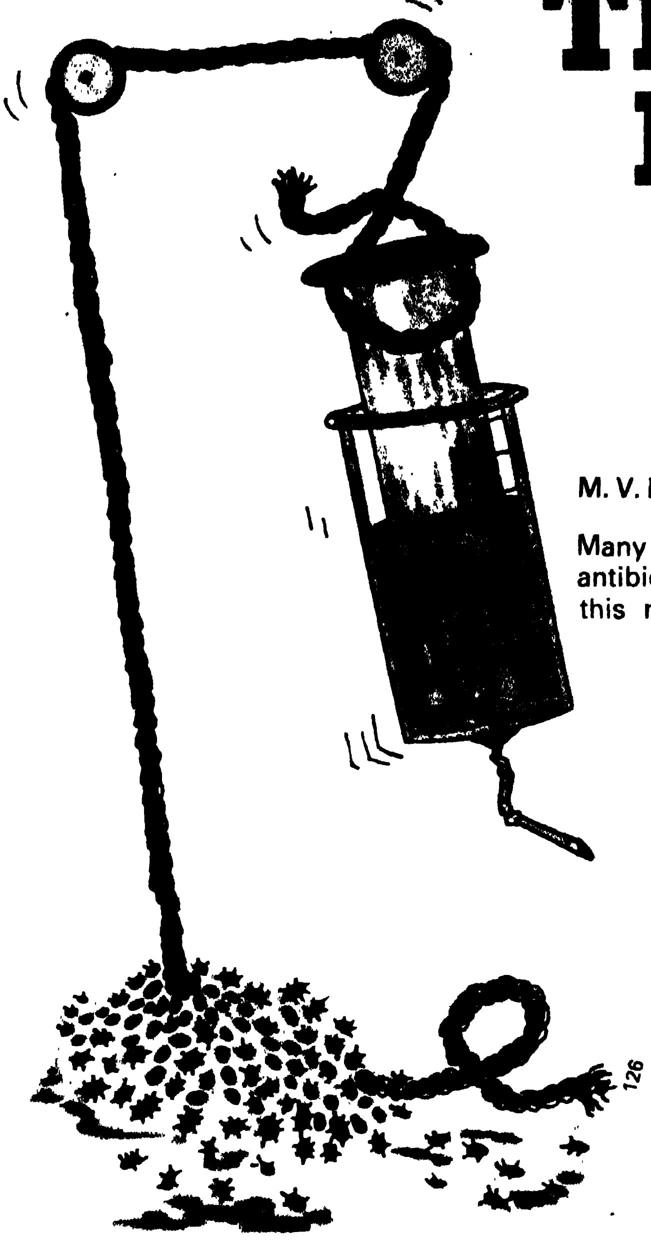


Fig 4. Special shaking equipment

In India, antibiotic research could be said to have started around 1960. Strain and product development are being continuously carried out and sustained. New antibiotics have also been discovered and some like hamycin are on the market as anti-fungal agents. India also produces in its private and public sector plants all the major antibiotics. Plans are on for gentamycin and rifamycin production, which are broad-spectrum antibiotics. However, the need would be to look for antibiotics which are active against water-borne diseases like typhoid, amoebiasis and other protozoal diseases. These are basically tropical diseases and research in India should concentrate on these.

Antibiotics have not only been used in chemotherapy but also in the laboratory for research purposes. In fact, they have become important research tools in molecular biology as they act as specific inhibitors of protein or nucleic acid synthesis. Its other non-medical uses include preservation of food, plant protection and treatment of bovine mastitis or other infections in animals. Also, certain antibiotics are generally added in small quantities to the feed of very young animals to stimulate the rate of growth. However, all these uses pose possible hazards to human health.

Prof Gopalkrishnan is at the Biochemical Engineering Research Centre, Indian Institute of Technology, Delhi. Earlier, he was the general manager for research and development at the Hindustan Antibiotics Ltd, Pimpri, Pune. After early education at Mysore University, he studied in the USA, and was a research associate and visiting scientist at several universities in the US and Europe.



THE BUGS FIGHT BACK

M. V. Panse

Many antibiotics no longer cure. Many other antibiotics are on death row. What causes this resistance to antibiotics?

DESPITE the wide availability of antibiotics, diseases like tuberculosis, dysentery, typhoid and venereal diseases continue to plague mankind. Cholera and bubonic plague erupt periodically—especially in Third World countries. Infections caused by *Staphylococcus*, 'hospital staph', are frequent in hospitals. Scientists had hopefully looked on the antibiotics as miracle drugs that will control bacterial diseases. But that was not to be. Though initially antibiotics proved effective against a number of bacterial infections, today the situation is different. Quite a few antibiotics have lost their effect on disease-causing organisms. In other words, these organisms have developed resistance to antibiotics.

What causes this resistance? In the beginning, it was believed that mutation (in the bacteria) occurring spontaneously, followed by selective multiplication of the resistant types, was the only cause. But, now we know that this is not true. Today, we have come a long way in understanding the mechanisms of drug resistance in bacteria. Apart from its importance in the medical field, the study of drug resistance offers new insights in the field of microbial genetics by elucidating the relationship between viruses, genes and other extra-chromosomal elements.

A drug inhibits the growth of a microorganism by affecting one of the vital functions required for the survival of the organism. For this, it binds to a specific target site in the susceptible cell. For instance, penicillins bind to specific sites on the cell-wall and block cell-wall synthesis; since the cytoplasm continues to grow this eventually leads to lysing (bursting open) of the cells and their death. Streptomycin, spectinomycin, kanamycin, gentamicin and erythromycin bind to specific locations on bacterial ribosomes (small structures made of protein and RNA and involved in protein synthesis mechanism of the cell) and lead to defective protein synthesis and eventual death of the cell. Chloramphenicol blocks the protein synthesis and thereby inhibits the cell growth.

Mutations in genes responsible for biosynthesis of the cellular structures to which the antibiotics bind normally (target sites) render the cells non-viable. However, in rare instances, the mutations do not make these structures non-functional, but destroy their affinity for the antibiotic. Such mutations make the cell resistant to the antibiotic. Similarly, mutations which modify permeability of the cell, so that antibiotics cannot enter the cell and find its target site, also impart resistance.

Fortunately, mutations leading to antibiotic resistance are very rare (between 10[illegible] to 10[illegible] per cell per generation). However, when such mutants arise even in one or a few members of the bacterial population exposed to the relevant antibiotic, most of the population succumb to the drug but the resistant mutants continue to multiply, eventually raising a whole population of resistance cells. This phenomenon of antibiotic resistance was observed with most antibiotics, within a short period of their introduction. In common manifestation of this phenomenon, the patient would first respond to an antibiotic but would suffer a relapse after some time and would no longer benefit from the same antibiotic. In most such cases, switching over to a new antibiotic would help the patient, with a few unfortunate exceptions where the infecting organism might develop resistance to the second antibiotic too. Such problems could be avoided, if the patient were put on a regimen of two antibiotics right from the beginning since the probability of resistance to both drugs arising simultaneously in the original population is exceedingly low.

It thus appeared that the antibiotics were the final answer to the infectious diseases, in spite of the cell's ability to throw up resistance mutants. All one needed was the availability of a small number of antibiotics to which a pathogen would be susceptible. This dream was, however, shattered in 1955 in Japan, with the appearance of the first documented case of a pathogenic organism which had developed resistance to a series of drugs and which could transmit this resistance to other (sensitive) organisms of the same or different species. In the rest of this article we will mostly discuss this transmissible multiple drug resistance which has since become a major worldwide problem in the path of using antibiotics to fight infectious diseases.

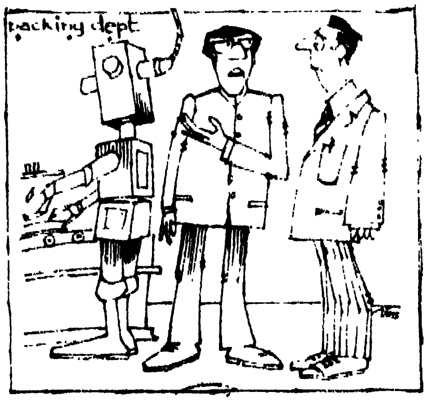
Historical perspective

In 1955, a Japanese woman, who had returned from Hong Kong was afflicted with a stubborn case of dysentery. What was unique about the bacillus of the genus *Shigella*, which caused the dysentery, was that chloramphenicol, streptomycin, tetracycline and sulphonamides had no effect on it. Only about a decade earlier, during World War II, sulphonamides (Su) were being routinely and effectively used against *Shigella*, which caused dysentery epidemics too frequently in Japan. But, this effectiveness was only short-lived. By 1962, more than 80 per cent of the *Shigella* isolates were highly resistant to sulphonamides. Same fate followed the introduction in Japan of the antibiotics streptomycin (Sm), tetracycline (Tc), and chloramphenicol (Cm) in the early fifties. And by the late fifties, a significant number of *Shigella* strains were isolated which exhibited resistance to more than one antibiotic—they exhibited multiple resistance. Japanese population was besieged by a number of unmanageable dysentery epidemics due to multiple drug resistance of *Shigella*. Subsequently, it was found, that *E. coli* strains which inhabit the intestines and form the normal flora of the human gut, were also present in resistant form in patients along with the resistant *Shigella*.

Coming to our Japanese patient from Hong Kong, through experiments, Tomoichiro Akiba of Tokyo University confirmed in 1959 that resistance to the four drugs was transferred from resistant *E. coli* to sensitive *Shigella* and from resistant *Shigella* to sensitive *E. coli*. Later on, the same kind of drug transfer was demonstrated in laboratory animals and even in humans by other researchers. The term resistance factor (R-factor) for the agent causing the infectious drug resistance was proposed by S. Mitsuhasi of T. Watanabe's group at Keio University School of Medicine, Tokyo. This term is widely used even today.

The world outside Japan learnt about the Japanese experience with these mysterious resistance factors in 1963 through Tsutomu Watanabe's detailed English language review of R-factors in *E. coli* and *Shigella*. Soon, it was found that R-factors were present in other bacteria too. Naomi Datta of Royal Postgraduate Medical School, London, reported R-factors in *Salmonella typhimurium*. G. Lebek of West Germany discovered R-factors in *E. coli* strains whilst R. P. Novick of Public Health Research Institute, New York, found similar factors in *Staphylococci*. Thus, within a span of a few years, the problem of transmissible multiple drug-resistance was observed throughout the world.

How could this multiple-drug resistance arise? Simultaneous modification of target sites for all the drugs, due to independent mutations could not occur at that high a frequency. The reason had to lie somewhere else. Indeed, it was soon found that the multiple-drug resistant bacteria frequently produced a high proportion of cells which were sensitive to all the antibiotics, implying that the target sites for these antibiotics had not been affected. The mystery was solved with the discovery that the key to the drug-resistance exhibited by these bacteria lay in their ability to modify the antibiotics with the help of certain enzymes, that they produced. The modified antibiotics could not recognise their cellular targets and, therefore, had no inhibitory effect on the cells. The enzymes which were responsible for inactivating the antibiotics were coded by genes located on extra-chromosomal circular DNA pieces. These DNA circles are R-factors, of Watanabe.


packing dept.

"Packing antibiotics all day had severe side effects on our men. So we got 'em robots"

Molecular nature of R-factors

As stated above, R-factors are units of DNA. These units carry the information for their own replication, for drug resistance, and their conjugal transferability. They are thus a class of plasmids, a term used to describe autonomously replicating extra-chromosomal DNA fragments.

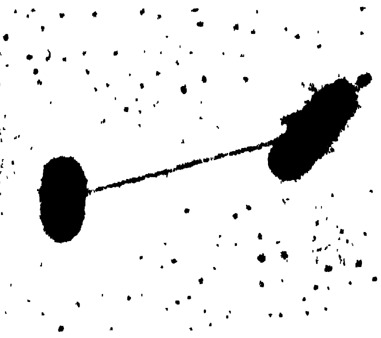
The R-factors were found to share many properties with the sex or fertility factor (F factor) of *E. coli* which had been studied earlier. Like the F factor they are normally cytoplasmic in nature and can promote their own transfer or transfer of other non-transmissible genetic elements present in the same cell. In rare instances, they are integrated into the chromosome and then they promote oriented transfer of the chromosomal genes. R-factor mediated DNA transfer also requires cell-to-cell contact and a conjugation tube (pilus) (See Figure on p.26). The structure of the pili produced by the R-factor is, however, different from the F-pili. And, the efficiency of the R-factor mediated conjugation is normally much lower than the F-mediated conjugations. Like the F factor, R-factors are also frequently spontaneously lost during cell division. Many of them can also be eliminated (cured) by treatment with acridine dyes, or other physical or chemical agents like ethidium bromide, sodium dodecyl sulphate, ultra violet light, etc.

R-factors have the property of spontaneously losing fragments of their DNA. They may also acquire additional fragments by translocation from other genomes (see box on p.28). The loss or gain of DNA fragments by these R-factors can change the number of antibiotic-resistance determinants carried by an R-factor. It can also at times lead to the loss of genes responsible for their conjugal transfer from one cell to another. The non-transmissible plasmids thus gentrated can spread in a population, either by bacteriophage mediated transduction or with the help of transmissible plasmids (plasmids carrying the genetic determinants for conjugal transfer) present in the same cell.

R-factor mediated resistance

R-factor induced drug resistance is due to production of an enzyme by a gene on the plasmid which inactivates the antibiotic or changes its permeability. The mode of inactivation varies with different antibiotics.

Bacteria which are resistant to penicillin produce an inactivating enzyme penicillinase (beta-lactamase). The beta lactamase hydrolyses the bond between the carbon monoxide and nitrogen (CO-N bond) in the beta-lactam ring of the penicillin molecule making the antibiotic inactive.



Electron micrograph of *E. coli* Note the F-pilus between the recipient and the donor

Resistance to different aminoglycoside antibiotics like streptomycin, kanamycin, etc is due to several enzymes produced by different R-factors. Several enzymes have been characterised which modify different groups of aminoglycoside antibiotics. These include *streptomycin adenylate synthetase*, which inactivates streptomycin, bluensomycin and spectinomycin by adenylylation; *streptomycin phosphotransferase*, which inactivates streptomycin, but has no effect on spectinomycin or bluensomycin; *kanamycin phosphotransferase*, which phosphorylates kanamycin, neomycin, paromomycin, and some components of the gentamicin and nebramycin complexes; *kanamycin acetyltransferase*, which acetylates kanamycin, neomycin, the hybrimycins, and some of the components [illegible] the gentamicin and nebramycin [illegible]plexes; *gentamicin acetyl transferases* I and II, which acetylate components of the gentamicin complex and tobramycin; and *gentamicin adenylyltransferase*, which adenylylates kanamycins, components of the gentamicin complex, and tobramycin.

[illegible]

TRANSFERABLE drug resistance in bacteria attracted the attention of Indian doctors only in 1972, following the discovery of such resistance in typhoid bacilli. By the mid-sixties R-factor-mediated drug resistance was present in many parts of the world. These involved the colon bacillus, causing urinary infections, salmonellae affecting people with food poisoning, dysenter bacilli, and many others. But there was one notable exception—the typhoid bacillus. Though closely related to the salmonellae causing food poisoning, it did not acquire drug resistance and chloramphenicol continued to be uniformly effective in the treatment of typhoid fever.

During 1970-71, Dr. Vimala, a post-graduate student in my department and I had found R-factors in colon bacilli from patients in Calicut, Kerala. These could be transferred to local isolates of typhoid bacilli in the laboratory. But such transfer did not seem to take place in nature. It was believed that typhoid bacilli would accept R-factors only in the presence of some strong selection pressure.

This selection pressure was provided during a large epidemic of diarrhoea which began in Kerala in December, 1971. Thousands of children were [illegible] in the last week. [illegible] 1972, [illegible] of typhoid [illegible] admitted in Calicut that did not respond to chloramphenicol treatment. Typhoid bacilli from such patients were found to possess R-factors which could resist up to a hundred times the dose of antibiotic required to kill "normal" typhoid bacilli. For the next several months, an outbreak of drug-resistant typhoid fever raged in North Kerala.

Publication of these findings caused much apprehension as the resistant strain was expected to spread. But somehow it remained an endemic problem in Kerala for the next several years. It was only from 1978 that drug-resistant typhoid fever has appeared in other parts of India in appreciable numbers.

At about the same time in 1972, a big epidemic of resistant typhoid occurred in Mexico. Though coinciding in time, these two epidemics were unrelated. The Kerala episode was not due to importation of the Mexican strain, but rather a direct result of the immense antibiotic pollution of the environment following oral antibiotic administration. The irony is that there was no need for any antibiotic use at all to control the diarrhoea epidemic, for we were able to show later on that it was caused, not by any bac-

MDR *Salmonella* epidemics in India

SALMONELLAE infections cause gastroenteritis, food poisoning and typhoid; they also cause protracted epidemics in hospitals, mostly among new-born infants with high fatality rates. In India, epidemics due to MDR *Salmonellae* have been studied at the Salmonella Phage Typing Centre, Lady Hardinge Medical College, New Delhi. Phage typing is a system of classifying closely related bacteria on their response to different bacteriophages.

Several epidemics caused by different species of *Salmonellae* have been recorded in the last few years. The first severe epidemic due to plasmid-carrying *Salmonellae* (other than *S. typhi*) was due to *S. newport*. It lasted from October 1975 to April 1977 and affected 237 new-born children in three hospitals in Delhi. *S. alachua* has been isolated in Calcutta from 65 children during 1971-77. Most of them suffered from meningitis, a complication of septicemia. Multiresistant strains of *S. wien* appeared in Algeria in 1973 and spread very widely in North Africa and continental Europe. In 1976, a few strains were encountered in Bombay, but fortunately it did not spread.

S. typhimurium is the commonest *salmonella* of human and animal origin all over the world. Before 1978 only 565 strains of *S. typhimurium* were reported by the National Salmonella Reference Centre over a period of 20 years (1958-77). Multidrug resistant strains of *S. typhimurium* first appeared in Bangalore in 1978 and very rapidly spread all over India, causing outbreaks in nurseries in hospitals. Up to December 1980, the isolations have been from Delhi (177 strains), Rohtak (26), Chandigarh (208), Amritsar (10), Bombay (179), Pune (33), Sevagram (42), Nagpur (4), Bangalore (210), Belgaum (22), Manipal (39), Calicut (75), Trivandrum (59), Madras (148), Vellore (232), and Madurai (46). These belong to the same clone of phage type 66/122/UT, which had also been encountered in the Philippines and the Middle East. The epidemiological features resemble that of *S. typhimurium* type 208, which also was distributed over wide areas.

S. typhi is by itself pathogenic; the strains that acquire a resistance plasmid lead to more severe complications. MDR in *S. typhi* was first observed in 1972 in Calicut. The focus has persisted till today. At Ernakulam, 200 km south of Calicut, 34 resistant strains were received from 1976 till the middle of 1978. This strain also did not spread to

[illegible]

[illegible] Coliform bacilli group consists of the coli bacilli, Klebsiellae and other related bacilli which are always present in the normal human intestines. They constitute the reservoir of R-factors, to the extent that 20 [illegible] per cent of strains isolated carry multiple drug resistance.

Dysentery bacilli: R-factors have become increasingly common in dysentery bacilli in India from 1976. At present, the majority of the isolates of the *Shiga* bacillus, the causative factor of bacillary dysentery, are resistant to several antibiotics.

Typhoid bacilli and other *salmonellae*: Drug resistant typhoid bacilli remained confined to Kerala from 1972 to 1978. From then on, they have appeared in Madras, Bombay, Chandigarh and other parts of India.

C. K. JAYARAM PANIKER

Dr. Paniker who is Director and Professor of Microbiology at the Government Medical College, Calicut, Kerala, discovered R-factors in India. He is the recipient of Dr. B.C.Roy Memorial National Award for Medical Research in 1978.

other cities. A self-contained outbreak occurred at Chandigarh in October-November 1979, involving 33 patients. Since October 1978, multiresistant phage type 0 has widely spread all over South India and by the end of 1980, strains of this clone had been received from Coonoor (36), Vellore (14), Bangalore (25), Madras (9), Madurai (46), Belgaum (25), Bombay (6) and Pune (4). In Calicut, this clone has replaced phage type C5 and 6 strains were received in 1980.

There is little doubt that the injudicious use of antimicrobial drugs on an international scale has contributed to the appearance and spread of the drug-resistant clones. The resistance plasmids also tend to attract virulence genes, which have led to increased virulence of these clones. A critical reappraisal of the use of antimicrobial drugs in developing countries should be done urgently.

K. B. SHARMA

Prof. Sharma is with the Microbiology Department, Lady Hardinge Medical College, New Delhi. Three reference centres are functioning in the above Department, namely, the [illegible] Streptococcal [illegible] Laboratory, the National [illegible] Phage Typing Centre, [illegible]

[illegible]

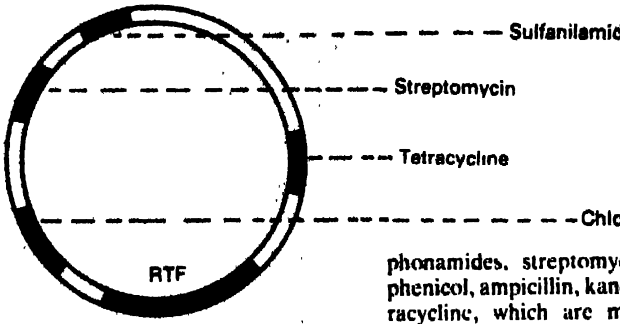
A SURVEY aimed at studying incidence of plasmid-borne drug resistance among healthy individuals and patients undergoing antibiotic treatment was carried out by Mr. V. Kaul, in collaboration with Dr. S. V. Weling, Chief Pathologist, Shushrusha Hospital and Prof. D. V. Tamhane of University Department of Chemical Technology, Bombay. From a sample of 123 healthy individuals (who had not consumed any antibacterial agent for at least six months prior to their examination), they could isolate 110 drug-resistant *E. coli* strains, of which nearly 46 per cent were multiple drug resistant (MDR). Several patterns of multiple drug resistance were observed, the most common being A, S, C, T, SU (that is, resistance to ampicillin, streptomycin, chloramphenicol, tetracycline and sulphamethazole).

Among the 75 patients, a total of 66 drug-resistant *E. coli* strains could be isolated, before the start of any antibiotic therapy. Of these, nearly 47 per cent were MDR. After treatment with an antibiotic, either ampicillin, tetracycline or erythromycin, nearly all the isolated *E. coli* strains were MDR and resistant to the specific antibiotic to which the patient had been exposed. Less than 30 per cent of all the MDR strains isolated from patients before antibiotic treatment could transmit their antibiotic resistance character to sensitive *E. coli* strains. This figure was over 50 per cent for the MDR strains isolated after the antibiotic therapy. Quite disturbingly, all the transmissible drug resistance factors could also be transmitted to *Salmonella typhi* the causative agents for typhoid infection.

A more extensive survey was carried out by Mr. V. M. Rangnekar in collaboration with Dr. S. V. Gadre, Dr. S. Mukherji and Dr. D. S. Chitnis of the Haffkine Institute, Bombay, in 1977-78. They screened 643 healthy subjects who had not consumed any antibiotics for at least one month before this study and 205 patients undergoing antibiotic treatment at different hospitals in Bom-

[illegible] group harboured MDR strains [illegible] the figure was nearly 66 per cent [illegible] second group. An interesting finding [illegible] this survey was a much lower (6 out [illegible] 100) incidence of MDR among [illegible] viduals of Bassein village, a rural [illegible] near Bombay, where exposure to [illegible] biotics is much less. Obviously, frequent exposures to antibiotics is responsible for the high occurrence of MDR strains among the urbanites.

Another survey was carried out [illegible] Mr. Rangnekar in 1980 at Sir Hurk[illegible] Hospital, this time in collaboration [illegible] Dr. D. D. Banker and Dr. H. J. [illegible] Drug resistance was found in *E.* [illegible] from nearly 60 per cent of 71 healthy adults and 92 per cent of 110 patients under antibiotic treatment at various hospitals. Though the survey was rather limited, it appears that the incidence of resistant *E. coli* has increased during the last two to three years. Resistance was predominantly for drugs like sulphonamides, streptomycin, chloramphenicol, ampicillin, kanamycin and tetracycline, which are most commonly used in the treatment of bacterial infections. Moreover, resistance, to the relatively new drugs, like gentamicin and trimethoprim, has also emerged.



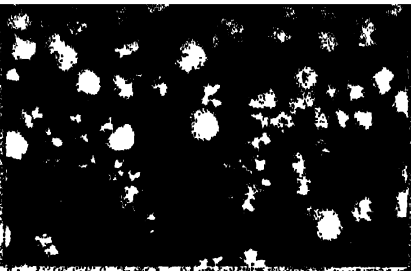
Genetic map of R-factor. Five determinants for resistance to drugs, and the determinant, the resistant-transfer factor (RTF), are shown

Drug resistance was also observed in different *Salmonella* species. The incidence of drug resistance was highest in [illegible] *typhimurium* isolated from cases of diarrhoea and systemic infections, whereas resistance is comparatively low in [illegible] *paratyphi* (8 per cent) and *S. typhi* (1 per cent).

Identical patterns of plasmid borne resistance were found in coexisting cultures of *S. typhimurium* and *E. coli*, indicating inter-generic transfer of R-factors by conjugation.

A disturbing finding of Rangnekar and his collaborators was the occurrence of plasmids of the so-called group H1 [illegible] their isolates. These plasmids have been associated with the typhoid epidemics which killed many people in Mexico and the South East Asian countries during 1972-74. Though the incidence of the H1 plasmids was low (one per cent) compared to other types of plasmids, their proportion can increase due to exposures to antibiotics.

B. S. MAHAJAN



[illegible] In recent years, scientists have been able to make reasonable speculations in this regard. Transposons are DNA pieces of [illegible] length which carry genes for specific metabolic functions and which can move from one location on a genome to other locations on the same or a different genome. In most cases, while appearing at the new location the transposons remain [illegible] their original position. Many of the genes conferring resistance to anti-microbial agents reside on transposons. Transposons carrying them have probably arose in organisms which had to survive in an environment containing antibiotics, for instance, the vicinity of antibiotic-producing fungi. In such environments the transposons may give a selective advantage to their host cells in which they might reside either on chromosomes or on extra-chromosomal genetic elements like plasmids or prophages. They can be transferred from their original host to newer ones by the common routes of genetic transfer, namely transformation, phage-mediated transduction or conjugation.

When two or more transposons of independent origin come together in a single cell, they often establish mutual association by translocation (transposition) on to a single genome, normally a plasmid. In this way plasmids carrying determinants for resistance to several antibiotics can be generated. Whenever such plasmids also pick up genes for their conjugational transfer, they become transmissible plasmids and can spread through a population very rapidly under favourable conditions. They have been observed to have a very broad host-range, that is, they can [illegible] for resistance to this [illegible] antibiotic until the [illegible] becomes resistant. [illegible] carries [illegible] several antibiotics, the [illegible] resistance to one antibiotic [illegible] population resistant to [illegible] antibiotics too. This is in contrast to antibiotic resistance conferred by chromosomal mutation. In the latter case, the probability of [illegible] resistance mutation occurring [illegible] is very low and, [illegible] resistance to one antibiotic, [illegible] surviving population [illegible] other antibiotics and multiple drug resistance does not normally arise.

[illegible] in not requiring extensive homology (similarity of base sequences) between donor and recipient DNAs and in not having an absolute requirement for the enzymes involved in the homologous recombination. Fusions, deletions, inversions and excisions of DNA segments are all examples of illegitimate recombination. Base sequence analysis in respect of several transposons has given evidence of a wide range of insertion specificities. Some transposons can insert themselves at almost any point on the host chromosome while others show a marked preference for a limited number of specific sites. In all cases so far examined, the insertion of a transposon is accompanied by duplication of a small host sequence (5 to 11 base pairs long) at the site of insertion. Replication of the transposon may also accompany their transposition, as some special enzymes—transposases—coded by the transposons appear to be involved in the process of transposition. A clearer picture should soon emerge.

B. S. MAHAJAN

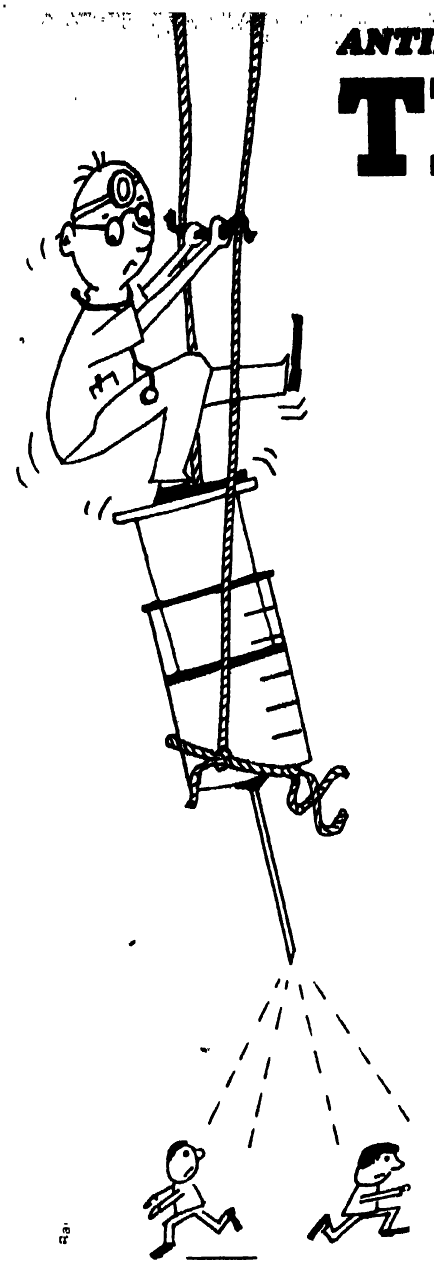
Chloramphenicol is a broad spectrum antibiotic used against enteric bacteria. Similarly, the R-factor for chloramphenicol resistance codes for a constitutive enzyme that catalyses acetylation of chloramphenicol in the presence of acetyl-coenzyme A. Through a series of acetylations, the antibiotic is rendered inactive.

Tetracycline resistance is probably the most common R-factor-mediated drug resistance in nature. Yet little attention has been paid to it. It seems that the resistance is due to the inability of the bacterium to concentrate the tetracycline in the cell and hence cell-permeability may be altered. Permeability may be the mechanism for R-factor-mediated resistance to sulphonamides, too. R-factors also mediate resistance to a number of heavy metals, colicins and ultraviolet radiation.

Impact on modern medicine

The high rate of incidence of multiple drug resistant organisms has become a serious worldwide problem. The fact that R-factors can be transferred to every genus of *enterobactariaceae* through non-pathogenic bacteria like *E. coli* has become a major public health problem. If a person harbours *E. coli* with R-factor in the intestinal tract, they can turn sensitive pathogenic organisms like *Shigella*, *Salmonella*, *V cholera* to resistant ones. It will then be difficult to control the infections caused by these pathogens. Since the use of new and old antibiotics is constantly increasing, both for clinical and agricultural purposes it is necessary to carry out an area-wide survey to access the incidence and extent of the multiple drug resistance. Otherwise, we may reach a situation when the future of chemotherapy can appear dubious.

Dr. Panse is Deputy General Manager of Hindustan Antibiotics Ltd. He is actively associated in research on multiple drug resistance.



ANTIBIOTICS

THE ABUSES

More than half the antibiotic prescriptions are unnecessary, and can cause serious problems

K. G. Nair

"DOCTOR, it all started with a running nose. And now I have cough, body ache and fever." "No problem," says the doctor. After a brief examination of the patient, he starts scribbling the names of a number of drugs. All too frequently, the patient comes back after a few days with no improvement in his general condition. The doctor now prescribes a fresh set of antibiotics. The patient may respond to this, or he may go to another doctor or give up the treatment altogether.

Many patients today receive more than one antibiotic at a time, and justifiably there is much concern about "antibiotic abuse". Though antibiotics constitute a major proportion of the drugs prescribed in modern medical practice, many doctors are unaware of the risks involved. Occasionally, the risks are predictable because of known pharmacology, but often the adverse effects manifest themselves only after exposure to the drug.

With hundreds of antibiotics in the market, some feel we have opened a Pandora's box, while others, like Richard Novick, chief of the Department of Plasmid Biology at the Public Health Research Institute in New York City, says: "In all fairness, I must point out that I do not foresee a global epidemic of untreatable plague as a likely consequence of antibiotic misuse... Nevertheless, there has been a series of serious epidemics of typhoid and dysentery in recent years in South and Central America. For those infected with hospital strains of *Proteus*, *Pseudomonas* and *Serratia* that are resistant to all clinically useful antibiotics, the miracle drugs might as well have never been discovered." But those whose lives have been saved by these miracle drugs think otherwise.

The main reason for the emergence of resistant bacteria which do not respond to a given treatment of antibiotics has been the massive overuse and misuse of antibiotics in humans and also in raising livestock. No reliable data are available in India on the quantities of antibiotic prescribed in various institutions, leave aside by private practitioners. In the US, however, it is known that more than 50 per cent of the antibiotic prescriptions are given without any evidence of bacterial or any other infection. It is estimated that nearly 80 to 90 per cent of antibiotic prescriptions are unnecessary.

The drug companies are too eager to push their products—of course, through the doctor. And the patients want to be cured fast by the miracle drugs. This vicious circle is to be broken, somehow. How, one does not know. Education, a sense of responsibility and even legislation must be enforced to prevent the antibiotic misuse.

No doubt, the marvellous cures antibiotics effect are impressive. But antibiotics misuse may well prove to be the nemesis of man. Perhaps there is more than a grain of truth in Ivan Ilich's criticism of the medical profession: Have we overshot the limits in the medicalisation of life?

Penicillins constitute a group of virtually non-toxic drugs, but sometimes toxic and allergic reactions do occur with fatal consequences. The penicillin group of antibiotics is excellent for pneumococcal (causing pneumonia and other infective diseases in humans) and for streptococcal infections. They are also effective against the common venereal diseases like syphilis and gonorrhoea. Unfortunately, hypersensitivity reactions do occur in some individuals. The allergic manifestations include rash, fever, bronchospasm (temporary narrowing of the ultimate branches of the windpipe due to violent involuntary contraction of its muscles), vasculitis, collapse due to hypersensitivity, and rarely death. It is mandatory for the physician to ask for a history of penicillin allergy before administering the drug. Unfortunately, this rule is not often adhered to and catastrophic results have been known to occur.

Penicillin (either by mouth or intramuscular injections) still remains the antibiotic of choice for the prophylaxis (prevention) of rheumatic fever—a crippling disease which damages the heart valves. The same drug, however, cannot be used to prevent wound infections. So often, one hears about the protective umbrella of antibiotics. But there is no substitute for the use of a good antiseptic before surgery.

It has become fashionable for the patients to ask for ampicillin (an amino-penicillin) now. However, this also causes drug rash in some susceptible individuals. It is not good to give ampicillin for a simple sore throat where oral penicillin will do; it is no more effective than penicillin. Further, it is too potent a drug for the condition. Frequent use will lead to resistance against the antibiotic. If the sore throat is due to infectious mononucleosis, a widespread skin eruption can result.

It is even worse to prescribe some of the newer semisynthetic penicillins such as cephalaxin, cephradine or cephalothin for common colds and fevers. These antibiotics are for special use against penicillin-resistant bacteria.

A number of fevers are caused by

viruses. Measles, mumps, chickenpox, and upper respiratory tract infections including even a simple sore throat—all belong to this class. To give penicillin or ampicillin in these conditions is meaningless. In fact, prolonged antibiotic treatment will lead to fungus infections, such as candidiasis which affects the skin, lungs, mucous membranes and viscera of man caused by a species of *Candida*. A female patient, who was given antibiotic treatment, which continued for 13 days, for common cold and cough ended up with a severe itching rash in the vaginal region. The gynaecologist, who was the second doctor visited, knew the patient well and promptly asked her: "Are you taking any antibiotics? If so, stop them immediately." Within a few days, the vaginal infection disappeared.

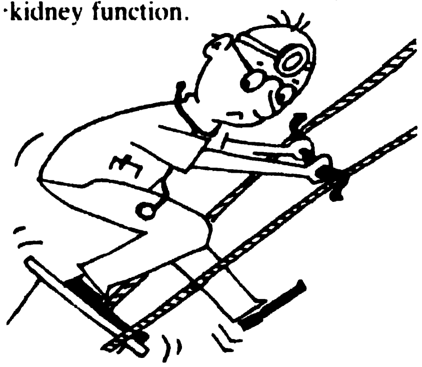
The rational approach to a fever is to discover its cause and treat it. When the doctor irrationally reaches for the antibiotic it is mainly to do something fast to satisfy the patient. The discerning patient will realise that antibiotics are not the cures for high fevers (antipyretics) and that most fevers are self-limited. Whenever possible, it is better to investigate the cause of the fever thoroughly than to take powerful antibiotics. Sometimes, the cause of a fever of "unknown" origin may be the antibiotic itself!

Cases continue to be reported of penicillin-induced hemolytic anemia where there is a decrease in the hemoglobin content and even in the number of red blood corpuscles. This usually occurs when high doses of penicillin are given. Some of the more severe, toxic reactions of penicillin cause severe and irreversible damage. There is a case history of a one-year-old whose hand had to be amputated. This extreme step had to be taken because, it seems, the doctors (unintentionally) gave an intra-arterial injection of penicillin which led to the development of a dead mass of tissue in the hand (ischaemic gangrene). Also, a peculiar neuropsychiatric reaction is known to occur to intramuscular injection of procaine penicillin. This comprises fear of death and auditory and visual hallucinations, and is popularly termed as Hoigne syndrome.

The semi-synthetic cephalosporins, though having a lot in common with the penicillins, are not so popular because of the distinct disadvantages associated with their administration. They are known to cause acute renal failure accompanied with tubular necrosis. Also, inferior activity against meningococci, gonococci, enterococci and *Hemophilus influenzae*, which cause meningitis, gonorrhoea, intestinal disorders and other serious infections in man, respectively, have been reported. Researchers also think that cross-allergy reactions between two groups of beta-lactam antibiotics are not impossible.

A group by itself, aminoglycosides include streptomycin, dihydrostreptomycin, neomycin, paromomycin (aminosidine), kanamycin, amikacin, gentamicin, sisomycin and tobramycin. Here, too, the side-effects are many and common amongst the different members of the group. They include toxicity to auditory-vestibular organs, specifically the right eighth cranial nerve and kidneys (nephrotoxicity).

Of late, gentamycin has become the most popular antibiotic because of its "wide-spectrum" activity. While it has truly proved to be life-saving in many cases, we are now seeing cases of resistance just as with the other antibiotics, Gentamicin is also not without toxic effects. It can damage the internal ear and adversely affect kidney function.



Macrolides, like erythromycin and oleandomycin, have relatively few side-effects. However, the occurrence of gastrointestinal disturbances limits the clinical use of these antibiotics. Erythromycin estolate and triacetyl oleandomycin are also known to cause toxicity in the liver. Of course, there is also the problem of development of bacterial resistance.

A new finding about oral administration of erythromycin estolate to babies should put mothers on guard. Gastrointestinal diseases are one of the most frequent disorders encountered in babies, especially when drinking water is not boiled and unhygienic sanitary conditions prevail. Too often, in the last few years, doctors in India have been known to prescribe erythromycin estolate to counter the disease. What are the consequences? It seems the pylorus, the orifice of the stomach communicating with the small intestine, gets obstructed due to hypertrophy of the thickened ring of muscles (pyloric sphincter) at the lower portion of the stomach. The baby constantly complains of abdominal pain as there is continuous spasm of the pylorus (pylorospasm). To a certain extent, this may also affect the overall stool formation, leading to bulky and foul-smelling stools.

Being "broad-spectrum", tetracyclines act on a wide variety of bacteria, and are, therefore, popular. Most of the tetracycline associated side-effects are related to the skin, teeth and bones, kidneys and the digestive tract. It should, however, be noted that most skin reactions which appear following tetracycline treatment are induced by excessive exposure to sunlight. This is further supported by the fact that 90 per cent of the skin reactions to tetracyclines are associated with demethylchortetracycline, the most phototoxic member of the group. For other tetracyclines, the skin reactions have a frequency of less than one per cent, at least in non-tropical areas. Five patients receiving tetracycline for six months for treatment of acne on the face developed red patches. Slowly, the other sun-exposed parts (at 57°C) became fragile and blisters formed. Apparently, the tetracycline is transformed by sunlight into an antigenic substance.

As most of the tetracyclines are only partly absorbed from the intestines, they remain in the gut for long and are known to change the character of the intestinal flora. Fecal coliforms decline in number but yeasts, enterococci, *Proteus* and *Pseudomonas* can overgrow. Thus, one form of diarrhoea may be replaced by another form which can prove fatal. Gastric and intestinal discomfort is also experienced in some patients after oral administration of tetracyclines. Some experience nausea too.

Children receiving tetracyclines may develop a brown discoloration of teeth. The problem is specially noted in newborns (neonates) and babies before their first dentition. Tetracycline also deposits in the bone as calcium orthophosphate complex, which affects bone growth adversely. Therefore, tetracycline is avoided in childhood, if possible from the fourth month in the uterus until eight years. Apparently, this is not followed by some doctors.

Sometimes kidney trouble may also be aggravated by this drug, especially when it is used after the expiry date. Pregnant women are occasionally prone to liver damage with tetracyclines, and one variety, demeclocycline, produces phototoxic reactions in susceptible people exposed to sunlight. Now it is generally accepted that tetracyclines, with the exception of doxycline and minocycline, are not to be given to patients with chronic renal failure.

Beta-lactams—utopian antibiotics

A MOLECULE of penicillin or its derivatives is made of 4-member beta-lactam ring, a 5-member saturated heterocyclic ring and a side group attached to the beta-lactam ring. Cephalosporins differ from penicillins in having a 6-member unsaturated heterocyclic ring. The key to the antibacterial properties of these compounds lies in the beta-lactam ring. It is this ring, especially the chemical bond between the nitrogen and the carbon monoxide which reacts with the enzymes involved in bacterial cell-wall synthesis.

The bacteria can inactivate the beta-lactams in one of the three ways: (a) by opening of the beta-lactam ring—a reaction which is catalysed by enzymes called penicillinases or beta-lactamases; (b) by splitting off the side chain—a reaction which is catalysed by amidases (acylases), and (c) by the removal of the acetyl group in the 3-position, in the substituted beta-lactams. This last reaction is catalysed by esterases.

All these enzymes are widely distributed in the microbial world. The widespread and often indiscriminate use of the antibiotics has resulted in a strong selection for resistant bacteria which have the capacity to produce one or more of these enzymes.

The most common cause of resistance, however, is the synthesis of the enzyme beta-lactamases by the bacteria. This fact led the researchers to look for compounds which inhibit beta-lactamases and also possess antibiotic activity. The discovery of compounds such as clavulanic acid, nocardicin, thienamycin, olivanic acid and PS-5 as natural products is an outcome of these efforts.

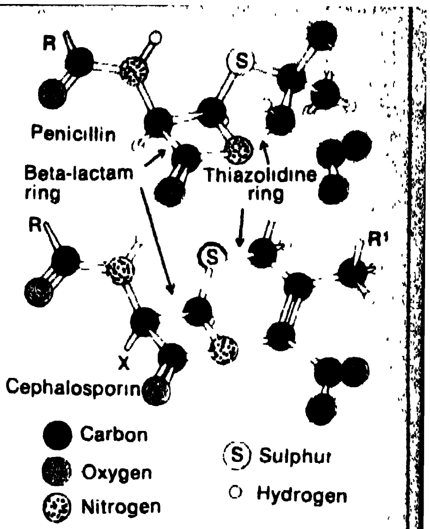
The first generation of antibiotics came out in the market as direct fermentation products. The need for modifying these was felt as scientists became more and more aware of the problem of inactivation. The modifications could be carried out purely chemically or biochemically.

For a long time, the chemical modifications of β-lactam antibiotics were limited only to the periphery of the intact (penam or cephem) nucleus. A very large number of side-chain modified penicillins and cephalosporins have since been reported. It is this approach which has brought out a series of β-lactams used in medicine, including the recent introductions of mecillinam, cetamandole, ceturozime, cetoxitin, the ureidopenicillins, cetachlor and cetotaxime.

The availability of chemical methods of transforming the penicillin nucleus into cephalosporin added yet another dimension to the semi-synthetic chemistry of β-lactams. As penicillins are cheaper and more readily available than cephalosporins, most of these procedures are restricted to the conversion of the 4:5 to the 4:6 ring system. However, a few transformations of cephems to penams have also been reported. The total synthesis of penams and cephems was the culminating point in the nuclear chemistry of β-lactams.

The sulphur in the heterocyclic ring is replaced by oxygen in clavulanic acid, a natural fermentation product. Such a compound is termed oxa-penam. The removal of sulphur from the ring-system makes it easier to synthesise penicillin and cephalosporin type of molecules. This approach, therefore, resulted in the synthesis of molecules with nitrogen, oxygen or carbon in place of sulphur (aza-, oxa- or carba-penams or cephems respectively). The emergence of azocillin, oxacillin, carbenicillin and the like is the result of the development of chemistry of β-lactams. Nuclear modifications of cephalosporins resulted in retaining the microbiological activity and increasing the potency against gram negative organisms in a few cases. However, the sensitivity to β-lactamases remained unchanged.

The biochemical modifications were carried out by feeding modified precursors to an antibiotic producing organism and by using enzymes to modify the antibiotic. Penicillin V, for example, was a result of feeding phenoxyacetic acid. An antibiotic, PS-5, was recently deacylated into a new β-lactam antibiotic (NS-5), with interesting therapeutic properties and which can be a useful intermediate for biological and chemical modification.



B-lactam is the key molecule of the penicillins and cephalosporins

The idealised situation is where we have an antibiotic which is highly potent, with a broad spectrum of activity, resistant to all inactivating enzymes and which is readily absorbed when administered orally. The techniques of protoplast fusion and recombinant technology hold great promise in this direction for recombinants can be obtained with a high frequency, and hitherto impossible genomic combinations can be achieved. The race is on, worldwide. Discovery of such an utopian antibiotic will be a major landmark in the history of β-lactams.

B. N. APTE

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Chloramphenicol, a broad-spectrum antibiotic, became unpopular in the West because of accompanying blood (hematological) disorders, often with fatal consequences. Now, chloramphenicol is used for specific indications only—typhoid and paratyphoid fevers, some septic forms of salmonellosis (infections with any species of *Salmonella*), serious infections like sepsis, inflammation of membranes of the brain and the spinal cord (meningitis) and acute epiglottis caused by ampicillin-resistant strains of the bacterium, *Hemophilus influenzae*. Thiamphenicol, a chemical analogue of chloramphenicol, is less likely to cause bone-marrow problems but it has not yet become popular. Blood disorders and pronounced immuno-suppressive effects have been reported to be associated with thiamphenicol therapy.

In general, chloramphenicol administration leads to bone-narrow damage, where there is a marked suppression of formation of red blood corpuscles and other blood components. This is more pronounced among the white races, leading to aplastic anemia. In new-born infants, the drug may cause "grey syndrome" This is manifested by vomiting, refusal to suck, abdominal distention, and the skin and the mucus membranes in different regions become blue due to deficiency of oxygen in the blood. The baby develops an ashen grey colour and this reaction can prove fatal.

Ears and eyes are also affected by chloramphenicol. Hearing defects or ototoxicity is commonly associated with local application of chloramphenicol. In one study, 12 cases with chronic inflammation of the middle ear (otitis media) were observed with asymmetrical hearing loss after treatment on one side with chloramphenicol powder. Because of its poor solubility in water, many manufacturers use propylene glycol as a vehicle for chloramphenicol ear-drops. Animal experiments have proved that both substances are highly ototoxic, if applied to the middle-ear cavity. Ear drops containing other antibiotics like neomycin or chlorhexidine are also suspected to be ototoxic. All ear-drops should, therefore, be screened for ototoxicity before marketing.

Chloramphenicol therapy may cause retinal bleeding, alterations in perceptions of colours, and inflammation and lesions of optic nerve (optic neuritis). Vitamin B deficiency is known to aggravate the situation, with more nerves being affected, even those of the legs, leading to paralysis. All this, of course after prolonged courses of treatment with chloramphenicol.

Antibiotic production

However, the most serious complication due to widespread and indiscriminate chloramphenicol use is the fast developing chloramphenicol resistance in *Salamonella typhi*, which causes typhoid, in several countries. This may eventually lead to the selection of R-factors (see p.24) coding for resistance to chloramphenicol and thiamphenicol, in addition to resistance to other antibiotics. Then we will be left with no antibiotics to combat typhoid.

Lincomycins and its semi-synthetic analogue, clindamycin, (7-chlorolincomycin) were fairly popular, as effective alternatives to penicillins, especially in known cases of penicillin allergy or resistance. Later, it was observed that patients receiving these antibiotics developed sudden bouts of diarrhoea preceded by acute abdominal cramps (colitis). Since the colitis intensity varied, it was inferred that these gastrodisorders were not a constant side-effect of lincomycin. Lincomycin is to be used carefully, especially in case of acne, where it is frequently advocated by beauticians. Heart failure (cardiac arrest) is known to occur with high doses. Fosfomycin (1-Cis-1, 2-apoxypropyl phosphoric acid calcium or sodium salt), which is effective against many infections (urinary tract, respiratory tract and even surgical infections), has many side-effects like disturbances of the gastrointestinal tract, diarrhoea, and temporary increase in levels of serum and other enzymes, leading to rash and disturbed vision.

Spectinomycin is an eminocyclitol antibiotic, lacking the broad toxicological spectrum of aminoglycosides. It is tolerated well in treatment of gonorrhoea. However, when given intramuscularly and in very high doses (two grams x four times daily), pain and other complications may ensue. Till now, no other adverse effects have been reported.

Local external use of systemically active antibiotics is a bad practice. Though penicillin skin ointment has been withdrawn, other antibiotics are still sold for local use on the skin. Abuse of this type can lead to local skin allergy and also the emergence of resistant strains of bacteria.

Antibiotic combinations

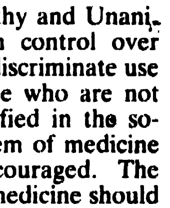
There are well-known rational antibiotic combinations such as penicillin-streptomycin, ampicillin-cloxacillin, ampicillin-gentamicin and gentamicin-carbenecillin. Handling of these combinations requires specialised knowledge. It is too unwise to use antibiotic combinations freely without knowing the organisms involved. Dangerous strains which are resistant to all the well-known antibiotics may emerge. The patient may then be rendered defenceless.

The use of unapproved antibiotic combinations are also many. Examples include penicillin plus tetracycline, kanamycin plus gentamicin, etc. In the former combination, the inhibition of bacterial growth and metabolism produced by tetracycline renders penicillin inefficacious as penicillin acts only on growing bacteria. In the latter combination, the two drugs have dangerous additive side-effects on the kidney and the internal ear. Both, renal damage as well as deafness can result.

When a large number of powerful antibiotics are used as in the case of diarrhoeas in children, the intestine is literally cleaned of both the 'good' as well as the 'bad' bacteria. This leads to superinfection. Yeasts, fungi and dangerous organisms, resistant to the usually given antibiotics, appear in the intestine. Thus, in many cases, the initial problem, for which treatment was given, gets aggravated. For most of the diarrhoeas in children, early oral rehydration therapy with glucose water, salt and soda bicarb is more than adequate. Unfortunately, panic reaction on the part of the patient's parents as well as the doctor causes the latter to reach out for powerful antibiotics first. It should be remembered that the gut also has 'friendly' bacteria which synthesise certain vitamins such as B12. For instance, vitamin K deficiency can occur with antibiotic use. The normal ecology of the bacterial flora of the gut can be badly disturbed by indiscriminate broad-spectrum therapy of diarrhoeas. Pregnant women should be particularly careful of taking powerful antibiotics like tetracycline, gentamicin, chloramphenicol, etc as they may damage the growing tissues of the foetus.

Antibiotics are truly double-edged weapons. Their misuse has indeed given modern medicine a bad name. One of the problems in developing countries like India is that antibiotics can be prescribed by doctors from other disciplines of medicine such as Ayurveda, Homeopathy and Unani. There is not enough control over their sale and use. Indiscriminate use of antibiotics by those who are not supposed to be qualified in the so-called allopathic system of medicine should also be discouraged. The euphoria of modern medicine should not lead to its own nemesis. Iatrogenic disease (physician-induced disease) need not be added to the ills of mankind. Do we have enough discipline in ourselves to use these powerful antibiotics in limited situations?

The educated citizen can be a strong force in the control of antibiotic abuse. It is well to remember that our Pyrrhic victories over small groups of organisms will not solve the problem, they may even aggravate it. The total number of bacteria in this world vastly outnumbers man. Maintenance of the ecological balance requires a rare wisdom not necessarily found in the commerce of medicine.



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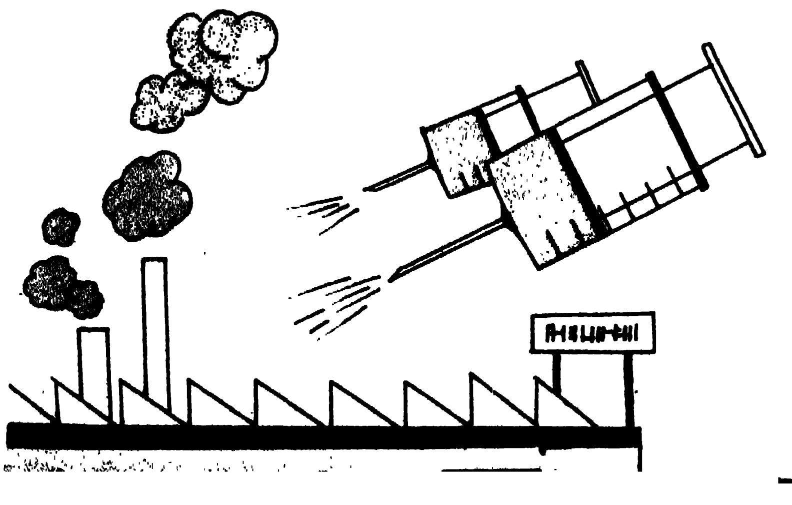
ANTIBIOTICS

THE SELLING GAME

J. S. Majumdar

The production and sale of antibiotics are not related to the actual needs of the people, but to the need to corner huge profits



DRUG companies often claim that newer antibiotics and other chemotherapeutic agents are discovered, produced and marketed to combat the development of bacterial resistance. Are antibiotics in our country marketed and promoted after considering this problem? Are they based on the actual necessities and requirements of the ailing people? A study of the marketing and sales promotion methods for antibiotics used by the drug firms will prove the contrary.

In the 1950s, five multinational drug companies entered the Indian antibiotic market with their sophisticated and aggressive marketing strategies. These companies were: Pfizer, Squibb in collaboration with Sarabhai Chemicals, Glaxo Laboratories, Cyanamid and Parke-Davis. While Glaxo, Squibb and Pfizer concentrated on penicillin and streptomycin, Parke-Davis started with chloramphenicol and Cyanamid with tetracycline.

The marketing strategies adopted by Squibb, Pfizer and Glaxo promoted combinations of penicillin and streptomycin for all indications, irrespective of their specificity—a blindfold therapy which ignores toxicity, side-effects and bacterial resistance. Subsequently, dihydro-streptomycin and its combinations were found to have serious toxic effects and were banned. Meanwhile, the combination market of streptomycin and penicillin was captured by Squibb and Pfizer. Even chloramphenicol, which was initially being promoted for specific indications, was later promoted for other indications, in order to outbeat competitors.

Gradually, these manufacturers also entered the field of broad-spectrum antibiotics like tetracycline and its derivatives. A competition developed between Pfizer and Cyanamid. Squibb and other companies followed suit. Pfizer found it more profitable to sell tetracycline than the penicillin-streptomycin combination. Sarabhai and Alembic continued to concentrate on penicillin and streptomycin and their combinations.

In the sixties, the tetracycline market started developing rapidly because of the aggressive marketing strategies of Pfizer, Cyanamid, Squibb, Hoechst and others. Pfizer soon established a firm grip on the market. To outbeat competitors, Hoechst came out with "Hostacycline 500" and claimed that its product had the advantage of a 12-hourly dosage over others who recommended a 6-hourly dosage. With this slogan, Hostacycline became an overnight success. Cyanamid then came up with Ledermycin 300 mg, also to be used twice a day, and rapidly expanded its market.

Sarabhai-Squibb did not want to lag behind either. It invented a new formula. It claimed that tetracycline and chloramphenicol with vitamin-C give better results. Sarabhai makes bulk vitamin-C and, therefore, its interest in this product was obvious. Originally, Mysteclin V, a combination of tetracycline and an antifungal, nystatine, had been marketed. The company had claimed that broad-spectrum antibiotics like tetracycline cause overgrowth of the fungus *Candida albicans*. Nystatine, being antifungal, helps prevent the overgrowth of this fungus. But nystatine had to be imported, and there were import restrictions. Sarabhai had to search for another slogan for marketing its tetracycline. As a result, Resteclin, a combination of tetracycline and vitamin-C was introduced. Later, Sarabhai introduced one more combination of tetracycline and another antifungal, amphoterin-B under the name Mysteclin V (improved formula). When marketing Resteclin, Sarabhai did not seem to be concerned at all about the overgrowth of *Candida albicans*. But while marketing Mysteclin V—improved formula (nobody knows how the import restriction on nystatine and switching over to amphoterin-B under this compulsion improved the formula), Sarabhai was very concerned with the overgrowth of fungus but completely forgot the role of vitamin-C with tetracycline. They are now happily marketing both the products.

Meanwhile, Abbott Laboratories entered the antibiotics market with erythromycin. Recently, however, the company found it less profitable to produce erythromycin and returned the letter of intent to the government. Consequently, the market for erythromycin is shrinking and other antibiotics are taking over. Obviously, the demand and sale of erythromycin do not seem to depend on the necessities and actual requirements of the drug.

In the seventies, newer antibiotics and other antimicrobials were introduced. Gentamicin by C. E. Fulford (better known as US Schering) was followed by co-trimoxazole introduced simultaneously by Roche and Burroughs Wellcome by an international agreement. But the government's drug policy (in 1970) put some restrictions on the multinationals. As a result, Indian firms, both private and public, are in the market with new antibiotics like cephalosporin, amoxycillin, doxycycline, cloxacillin, etc. But their marketing strategy is no match for the sophisticated and aggressive marketing strategy of the multinationals. Therefore, the newer indigenous antibiotics are selling in the market more on an ad hoc basis and without a brand leader. And the public sector today has a negligible share in the antibiotics trade.

Streptomycin-penicillin combinations still account for a large share. The market share of other antibiotics, including chemotherapeutic agents (except narrow-spectrum antibiotics like penicillin and streptomycin), in 1979 was—tetracycline 45.5 per cent, ampicillin 12.8 per cent, co-trimoxazole 14.9 per cent and gentamicin, erythromycin and others 25.8 per cent. The old formulations are still going strong. Among other antibiotics, the multinationals control the lion's share, leaving only a small fraction for the Indian sector with the newer antibiotics. So much then for the claim that it is the development of bacterial resistance to antibiotics that has necessitated the introduction of new antibiotics.

Pricing strategies

The pricing strategies of the multinationals shows the profitability of their products. With the drug price control order (DPCO), 1970, the prices of tetracycline and chloramphenicol were cut by half. The price of tetracycline was further reduced later. Yet, the multinational drug firms found that they could earn huge profits in tetracyline. Tetracycline, therefore, remained the first item in their promotional plan. The pricing of tetracycline multi-dose vials exposes the break-neck competition and the wide margin of profits. The ten ml vial of Terramycin IM (the multi-dose vial of oxytetracycline 500 mg marketed by Pfizer), which cost more than Rs. 10 per vial before 1970, was sold around Rs. 5.00 per vial following the DPCO. Even then, Pfizer found substantial profit in this product and geared all its promotional activities to capture a huge market.

Sarabhai and others were keenly watching the expansion of the market for Terramycin IM vials and its profitability. Sarabhai introduced a similar product—Oxysteclin. A fierce competition ensued. Pfizer introduced an incentive scheme of 30 vials free for the purchase of every 100 vials. Sarabhai followed with the same offer immediately on introducing the drug. Others too joined the fray. A ten ml Terramycin IM vial now costs Rs. 3.22.

Pfizer also introduced a novel scheme of "Poor Patients Sampling". Under this scheme, huge quantities of ten ml Terramycin IM vials are given as samples. Sarabhai and other companies soon followed suit. Sarabhai introduced a 20 ml vial of oxytetracycline under the generic name costing Rs. 4.05 per vial declaring, in addition, a ten per cent bonus offer. The same product, under the brand name Oxysteclin, continues to cost Rs. 3.23 for the ten ml vial. In a special campaign for Acromycin IM, Cynamid declared still more lucrative incentives, like 48 vials free for the purchase of every 52 vials! Alembic offered a stainless steel utensils scheme for purchasers of Alcycline vials. Other manufacturers offered suit cases.

While introducing an antibiotic, a multinational company keeps the retail price of its product under a brand name phenomenally high. It refuses to bring down the prices till it is compelled to compete with the same product marketed by another company under its generic name. A glaring example is Garamycin marketed by C. E. Fulford. Gentamicin sulphate 80 mg, under the brand name Garamycin, was introduced by the company in 1969. Every vial at that time cost about Rs. 35. This was brought down to Rs. 28.77 per vial in 1976. However, when it began to face competition from the Indian sector and the product became available under the generic name, the price of Garamycin was brought down sharply to Rs. 11.41 per vial. This price is still the highest amongst all other brands of the same product. Hindustan Antibiotics Ltd, a public sector undertaking, offers a special rate of Rs. 5.80 per vial of this product for hospitals, though the general market rate for a vial of HAL Gentamicin is Rs. 9.80.

It is these huge margins, and not the safety and effectivity of drugs which lie behind the sales drive of the multinationals. They decide what antibiotic is to be used, and when they do, they can expand the market whenever they like. For instance, Cyanamid, the US multinational, did not give much emphasis on the sale of Ledermycin during 1975 to 1978. However, in 1980-81, the company decided to promote the product as the first priority item and make up the loss in the sales turnover of the company due to the withdrawal of products like Acromycin,, Ledermycin drops and syrup, Delphicol, Lederkin, etc. And the company succeeded in increasing Ledermycin sales by 30 per cent in 1980-81.

Over the years, the situation, if anything, is getting worse. When more and more information is piling up about drug resistance and side-effects, many companies are now dispensing with the practice of packaging relevant information along with their products. In their sales drive, visual aids and tailor-made detailing folders are taking the place of detailed information sheets on side-effects, toxicity, contra-indications, etc. Claims are supported by clinical trial reports published in various parts of the world but medical journals show that this often does not take into account the ongoing nature of the work or the conflicting findings in other trials.

Antibiotics are often promoted for use in post-operative conditions as proper hygienic conditions are not available in most hospitals, nursing homes and clinics. Today antibiotics are routinely administered even when unnecessary. A general line of selling is that, since detailed pathological investigations are not feasible in routine day-to-day therapy, antibiotics offer an easy substitute for careful diagnosis. This has sinister implications in rural areas.

Another dangerous trend is to promote antibiotics among unqualified persons in rural areas. Drug companies encourage unqualified persons to use their antibiotics indiscriminately. They are visited regularly and given short-term lessons by these companies about the use of antibiotics with scanty attention to the hazards involved. And to bypass the law, these unqualified persons are often mentioned as doctors with an "RMP" (Registered Medical Practitioner) tag for qualification.

The fact is, there is no firm antibiotics policy in the country. The drug manufacturers, particularly the multinationals, decide and dictate the antibiotic market and the usage of antibiotics. They take serious objection and do everything to resist any attempt for an institutionalised approach in the production, marketing and use of antibiotics. And they take full advantage of the personalised approach in treatment by medical practitioners.

Many antibiotics often promoted by the drug manufacturers, particularly the multinationals, have been found to be banned in the countries of their origin. Profits, after all, must come before people's health, especially if they happen to be a Third World people. Our antibiotics policy has so far left the matter in the hands of these very companies. The only alternative is to have an institutionalised approach based on a clear and firm antibiotics policy.

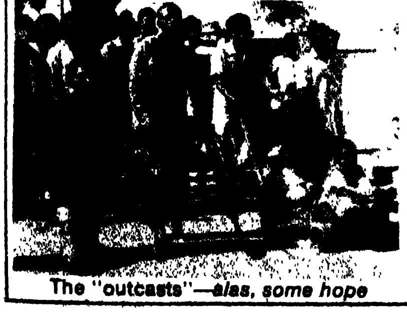
Mr. Majumdar is the General Secretary of the All India Chemical and Pharmaceutical Employees' Federation and also of the Federation of Medical Representatives' Associations of India. He represented the Indian pharmaceutical workers in the International Conferences of Trade Unions several times and is a member of the Preparatory Committee for the World Conference against Transnational Pharmaceutical Companies

Soon, a leprosy vaccine?

DESPITE remarkable advances in vaccine production technology, there still remains, particularly in the tropics, a number of infectious endemic diseases against which no useful vaccine is available. Prominent among these is leprosy. It is possible that the attempts at developing a vaccine for control of leprosy had not acquired momentum since it is not a fatal disease. However, it is a crippling and disfiguring disease making the affected person a virtual outcast. In the past, powerful drugs like dapsone or rifamycin were able to bring about a satisfactory cure. Recently, however, reports of emergence of drug-resistance have caused acute concern, and even the WHO has advocated serious efforts at developing an efficacious vaccine.

Such efforts are handicapped by certain peculiar characteristic features of this disease. Only in the recent past it has become possible to cultivate *Mycobacterium leprae*, the causative organism for leprosy, first by growing it in the foot pads of mice and later in nine-banded armadillo. However, these procedures do not provide *M. leprae* in adequate amounts for producing a vaccine. Also it's overt manifestation presents a wide spectrum spread between the two polar forms of tuberculoid (TT) and the lepromatous (LL) leprosy. This spectrum also correlates well with the status of immune response in these forms. The tuberculoid patient lacks humoral response to *M. leprae* but possesses vigorous cell-mediated immunity (CMI), which is protective by keeping the bacillary load in check. However, at times, a strong CMI can cause nerve damage leading to atrophy of the extremities. The lepromatous patient presents a mirror image of this immunological picture, but the CMI is virtually absent. Consequently, such a patient possesses large amounts of bacilli and thus poses the real danger of spreading the infection.

Unlike all the other vaccines, a potential vaccine in the case of leprosy has thus, to perform this feat of selective induction of CMI. The recent report of the development of such an anti-leprosy vaccine by M.G. Deo and C. V. Bapat of the Cancer Research Institute, Bombay and R. C. Chulawalla and W. S. Bhatki of the Ackworth Leprosy Hospital, Bombay, (*Indian Journal of Medical Research*, 74 164) suggests indeed that this requirement has been fulfilled.


The "outcasts"—*alas, some hope*

The significance of this development, which appears to be totally indigenous, lies in the use of radiation-killed ICRC bacillus for the vaccine. This organism which belongs to the mycobacterium family, was isolated originally from the lepromatous nodule of a LL patient. It possesses the same morphological features and growth characteristics of *M. leprae.* Several laboratories have reported that antigenically also it is close to *M. leprae* The obvious advantage in using ICRC bacillus is that it can easily be cultivated in the laboratory without change in its antigenic make up. This has been amply demonstrated by the authors, as it has been under continuous passage for the last twenty years. Consequently, adequate quantities for the vaccine production can be obtained.

The present report is novel since it describes a human trial of the vaccine. It also provides information on two important aspects of efficacy of the vaccine. First, 50 per cent of the vaccinated LL patients showed generation of CMI and the bacillary load, which is an indirect measure of the infective potential of these patients, was substantially reduced. Second, over a period of 15 months no untoward or toxic side effects have been observed.

It might be argued that, since the vaccine has been used in leprosy patients who have not only been exposed, but fully affected by the infection, the procedure does not constitute vaccination but rather immunomodulation. But, normal healthy individuals also possess an inherent natural resistance to leprosy and even among contacts fully 80 per cent have adequate CMI. Further, this procedure would lead, as claimed, to a sizable reduction in the infective population—thereby enabling control of the spread of infection. In this regard the use of the vaccine should be considered preventive.

Notwithstanding these promising features, the present report on the vaccine should be considered only as a first step, albeit in the right direction. There should be no euphoric shouts of an ultimate remedy. The number of patients tested would have to be increased to statistical levels, preferably in a multicentric trial. A vigilant watch would have to be kept for a longer period on the toxic effects if any, and the success rate is still only 50 per cent.

These observations, still make it tempting to speculate that perhaps the use of more than one mycobacterial strain in the form of a polyvaccine could generate strong CMI The *Mycobacterium w.* being tried out by the group at All-India Institute of Medical Sciences led by Prof. Talwar could perhaps be a useful candidate for this purpose.

G.P. PHONDKE

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Tinkering with nitrogen-fixing genes

ONE of the major hot-spots in biological research today is to evolve non-leguminous cultivars—(cultivated varieties) such as rice, corn, wheat, etc which can utilise atmospheric nitrogen in a similar way as the leguminous crops (soyabeans, beans, etc). The major strategies include (i) discovering new microorganisms which can fix atmospheric nitrogen in close association with the roots of cereals; (ii) developing organisms that can fix atmospheric nitrogen which can then be utilised by the crop; (iii) transferring nitrogen-fixing (*nif*) genes that control the synthesis of nitrogenase enzyme to non-leguminous crops by recombinant DNA techniques; and (iv) evolving strains of *Rhizobia* (a group of symbiotic bacteria which fix atmospheric nitrogen in close association with the roots of different leguminous species) which can nodulate and fix nitrogen in a wide range of crop plants.

During recent years the *nif* gene-complex (comprising 17 structural genes) has been mapped, and a large number of plasmids, (autonomous, self-replicating pieces of bacterial DNA) carrying the *nif* genes have been constructed. But there are problems associated with the expression of *nif* genes in the cellular environment of recipient organisms. Therefore, regulation and expression of these genes in their native environment is being studied.

It had been demonstrated earlier that the structural genes for the nitrogen-fixing enzyme (nitrogenase) from different organisms, had considerable base sequence homology as revealed by molecular hybridisation experiments.

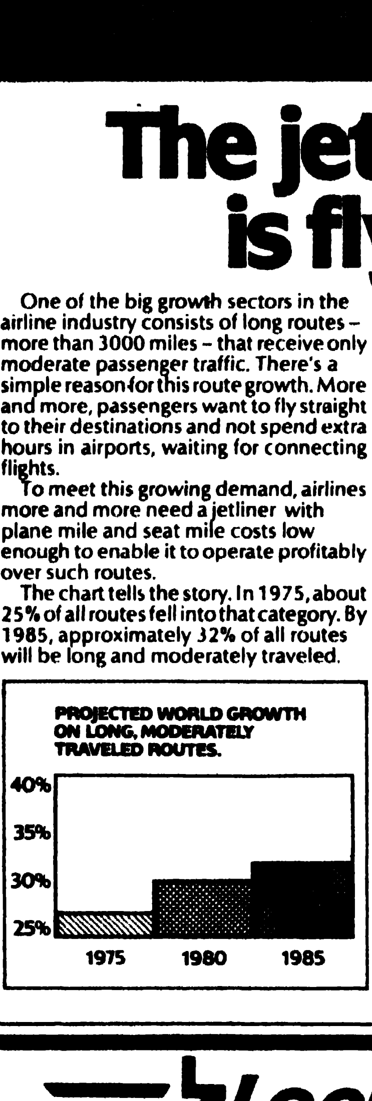
Recently, H. Hennecke, (*Nature* **291,** 354) investigated the DNA sequence homology between fragments of the *nif* gene complexes from *K. pneumoniae* and

The jetliner of the future is flying right now.

One of the big growth sectors in the airline industry consists of long routes – more than 3000 miles – that receive only moderate passenger traffic. There's a simple reason for this route growth. More and more, passengers want to fly straight to their destinations and not spend extra hours in airports, waiting for connecting flights.

To meet this growing demand, airlines more and more need a jetliner with plane mile and seat mile costs low enough to enable it to operate profitably over such routes.

The chart tells the story. In 1975, about 25% of all routes fell into that category. By 1985, approximately 32% of all routes will be long and moderately traveled.



The right-size plane at the right time.

The fourth and newest member of Lockheed's L-1011 TriStar family, the long-range L-1011-500, uniquely fills the need for a comfortable jetliner able to operate profitably on long and moderately traveled routes.

It has three engines so that it can be certificated to fly over long stretches of ocean. Thanks to its slightly smaller size and advanced technology, it has plane mile costs 8 to 10% below those of its nearest competitor, according to a giant airline that chose the L-1011-500. Big, four-engine jetliners, of course, cost a lot more to purchase and operate than three-engine jetliners. In fact, no big, long-range jetliner can match the L-1011-500's combination of low plane mile and seat mile costs. And its wide cabin provides the roomy comfort that passengers demand on long flights. It's spacious enough to satisfy passengers and sized right to satisfy airlines.

L-1011 Technology: years ahead of other jetliners.

Look at those long wings on the L-1011 in the picture above. They've been stretched nine feet to help increase fuel efficiency. An exclusive system of Active Controls made this possible. (You'll find Active Controls on jetliners of the future, but now only the L-1011 has them.)

The L-1011 also has the world's most advanced Flight Management System. This exclusive system automatically selects the best speed and power levels and then controls throttles in flight to conserve fuel.

And the L-1011 is advanced in many other ways. It routinely lands at some airports, for example, in bad weather that turns other jetliners away.

The $150 billion market.

There is broad agreement among aerospace and financial communities that the market for new aircraft will range up to $ 150 billion between now and 1990.

Major growth lies ahead.

Some of the new twin-engine jetliners will serve the short-and medium-length routes in that market. But only the long-range L-1011-500, with its exclusive, years-ahead technology, can meet the demands of one of the key growth sectors of that huge market.

If you're interested in opening up new, long-range routes, hadn't you better get interested in the right-size jetliner that gives you the competitive edge – the lowest combination of plane mile and seat mile costs?

Lockheed L-1011 TriStar

6687/

R. japonicum using recombinant DNA and molecular hybridisation techniques. The results conclusively proved that only two *nif* D and *nif* H) out of 17 *Klebsiella nif* genes shared common DNA sequences with *nif* region of *R. japonicum*. It was also evident that the interspecies hybridisation seen earlier was based mainly on *nif* H and *nif* D homologies, implying divergence in DNA sequences coding nitrogenase complex in different organisms.

To evolve *Rhizobium* species having a wide host-range, it is essential to investigate the genes involved in symbiosis and root nodulation. Genetic and biochemical studies on *Rhizobium leguminosarum*—a symbiont that nodulates peas and vetches (annual legumes) revealed that genes on a large plasmid are involved in root nodulation. R. A. Schilperoort and his associates *(Nature* **291**, 351) demonstrated that the genes on one particular plasmid-Sym of *Rhizobium trifolii*, determined host specificity, and controlled several steps leading to root nodulation and subsequent nitrogen fixation on clover roots. The genetic manoeuvers adopted by the authors were simple crossing (conjugation) experiments involving different strains of *R. leguminosarum*, *Agrobacterium tumefaciens* and *R. trifolii* These contain the plasmid (pRtr5a), which promotes its own transfer and carries symbiotic nitrogen-fixing genes.

In one set of experiments the authors developed non-nodulated (Nod) strains sensitive to Kanamycin (Km). All these Km Nod strains had lost a plasmid of molecular weight 180×10^6. When this plasmid was reintroduced into Km Nod strains by conjugation, the recipient strains became Nod$^+$ (nodulated and capable of nitrogen fixation). These experiments clearly proved that pRtr5a plasmid controlled nodulation. In the second set of experiments the researchers introduced pRtr5a plasmid into several *R. leguminosarum* strains which nodulated only peas and vetches, but not clovers. These recipient strains nodulated their specific hosts (peas and vetches), and clovers too. However, when pRtr5a was transferred to a mutant of *R leguminosarum* which does not nodulate peas and vetches, the recepient strains nodulated clovers, but not peas and vetches. These results suggested that the plasmid pRtr5a contained genes that determined host specificity. Earlier results of R. K. Prakash had revealed that Sym plasmid carried at least some of the *nif* structural genes, whilst H. Hennecke had speculated that the plasmid PR J676 carrying *nif* D, *nif* H and *nif* K of *R. japonicum* contained genes which coded for proteins of the symbiotic nitrogen-fixing apparatus.

In a third set of experiments, the authors have studied the expression of the plasmid pRtr5a in *Agrobacterium tumefaciens*. They introduced plasmid prtr5A of *R. trifolii* into a *A. tumefaciens* strain which was free of Ti plasmid (that carries genes for tumor induction). The *A. tumefaciens* cells which had acquired the pRtr5A plasmid could not bring about proper nodulation.

These results conclusively proved that Sym plasmid of *R. trifolii* carried genes that controlled not only host-specificity but also the processes involved in root nodulation.

Still, there is a long way to converting a non-nitrogen fixing bacterium into a nitrogen-fixing one. But genetically engineered hybrid plasmids carrying the requisite genes may perhaps solve many a problem, and also lead to gene transfer into eukaryotic systems.

C. R. BABU
N. C. JAIN

Dr. Babu has been investigating the genetical and biochemical aspects of wild relatives of food legumes at the Department of Botany, University of Delhi, Delhi. Mr. Jain is a research student at the same department.

Radio-carbon dating by infrared lasers

SINCE 1947, when it was discovered by W. F. Libby and co-workers, radio-carbon dating has been a revolutionary tool for estimating the age of materials containing carbon which have formed within the last 70,000 years. C^{14}—the radioactive isotope of carbon—is formed in the atmosphere by the interaction of nitrogen (N_2) with neutrons produced by cosmic rays. C^{14} decays back into nitrogen 14(N^{14}), through beta particle emission, with a half-life of 5,730 years. The radioactive carbon along with stable carbon C^{12} combines with the atmospheric oxygen to yield carbon dioxide ($C^{14}O_2$). Through photosynthesis, plants take in atmospheric $C^{14}O_2$ and thus radiocarbon becomes part of them. The same is the case for human beings and animals which take in plants as their food. Any decay in C^{14} would be compensated by a fresh intake of C^{14} from the atmosphere. This results in a equilibrium concentration of C^{14}, if the production rate does not change, in the atmosphere as well as in all living vegetable tissues, animals and human beings. When a plant or an animal dies, there is no further addition of C^{14} to its tissues: and in fact, the amount of C^{14} in them starts decreasing because of radioactive decay. Given the concentration of C^{14} when the organism died—which is the equilibrium concentration of C^{14} in the atmosphere—the time elapsed after its death can be determined from a measurement of the C^{14}/C^{12} ratio in the tissues.

Conventional dating techniques measure the beta activity of dead carbon samples (bones, peat, charcoal etc) to determine the remaining C^{14} concentration and, hence, the sample's age. Accuracy of measurement is generally limited by the tiny fraction of C^{14} atoms which disintegrate during the counting period; for living materials there are approximately 15 disintegrations per minute per gram of natural carbon. Clearly, a more sensitive method of radio-carbon dating would be to directly measure the C^{14} remaining in the sample rather than to measure the small number of disintegrations.

Laser-physicists, from McMaster University, Canada, have recently reported one such direct method of dating archaeological samples by using infrared laser absorption spectrometer (LAS) (*Applied Physics* **24** 381). They first converted the carbon sample into CO_2 and then measured the absorption coefficients of the strong vibration-rotation lines in the ν_3 (ν_3 = frequency) band of $C^{14}O_2$ near 4.5 microns. This would give a direct measure of the remaining C^{14} concentration. The ν_3 band was chosen because this is one of the strongest absorption bands in the infrared of $C^{14}O_2$. A combination of a tunable diode laser and a multipass optical cell were used to achieve the required resolution and sensitivity They also show that the detection of $C^{14}O_2$ at concentrations of C^{14}/C^{12} less than or equal to 10^{15} is not limited by interferences from the background of normal CO_2 molecules, provided the gas sample is cooled to dry ice and the background subtraction technique is used. This laser technique would enable samples as small as a few hundred miligrams of carbon to be dated; this is not possible with conventional counting technique due to the statistical uncertainty in the number of counts, and the presence of background radiation. To be more specific, LAS can detect C^{14} in samples that decay once in every nine minutes with a sensitivity of five parts in 10^6.

Recently, very impressive results on C^{14} detection have been achieved using accelerators (*Physics Today*, February 1979, 23). Although this technique offers a highly sensitised detection of the C^{14} remaining in the sample, its use could be limited because of the expense and non-availability of accelerators. The LAS cannot compete in sensitivity with accelerator technique of radio-carbon dating, but it will be much less expensive. The LAS can also be used for the measurement of small abundances of other stable and radioactive isotopes.

DHRUBA JYOTI BISWAS

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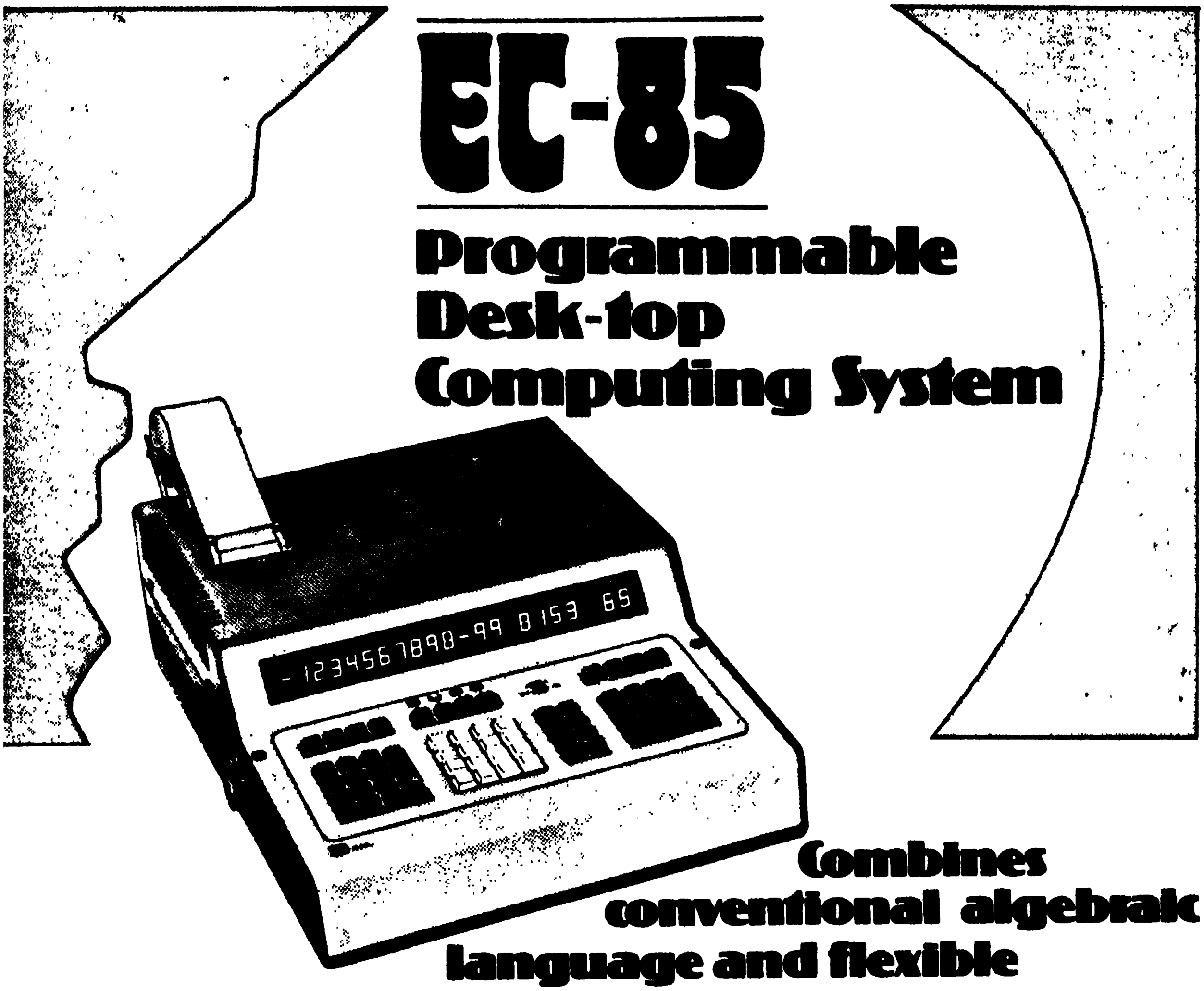
EC-85

Programmable Desk-top Computing System



Combines conventional algebraic language and flexible programmability to meet the computation needs of professionals

An engineer, a statistician, an economist, a finance executive, a scientist — the computation needs of each may be different from the others. EC 85, a powerful desk-top computing system featuring conventional algebraic language and flexible programmability, is specially designed to meet a wide range of challenging computation problems confronted by professionals. The basic system comprises the complete scientific and statistical keyboard, a display, a printer and powerful programmable facility up to 2000 programme steps and 200 memory data registers. What's more, it's compatible with a wide range of peripherals. And fully open for expansion in respect of programme steps and data registers. In short, it's a system that can suitably expand and keep pace with your expanding computation needs and requirements.

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Mapping The Earth's Magnetic Field

B.P.Singh

Space-borne magnetic surveys may help find new mineral resources and unravel the Earth's mysterious past

IN THE year 2634 BC, a great battle was fought in the plains of Tcho-Iuo between the Chinese emperor Hoang-Ti and a minor prince, Tchi-Yeau. The prince produced a dense fog—the ancient equivalent to the modern smokescreen—to confuse his enemy. The emperor was smarter. He put a small statue of a man, with one of its arms always pointing towards the south, on a chariot. With its help, the emperor's army was able to pursue the retreating enemy. The prince was captured and put to death.

The ancients knew the use of magnetic compass for navigation. They thought that the compass-needle always pointed towards the Pole-star in the North. The modern scientists have gone a step ahead. They are using space technology to obtain the most accurate and up-to-date quantitative description of the Earth's magnetic field to locate potential mineral and oil resources and to mark out earthquake-prone areas.

The earth's magnetic field is unsteady and complex

In 1600, William Gilbert, a physician to Queen Elizabeth of England proclaimed that the globe of the Earth itself is a great magnet. Studies revealed that the Earth's magnetic field contained contributions from three sources. The main field could be described as similar to that produced by a huge bar magnet, with its centre near the centre of the Earth and with its axis tilted at an angle of about 11" to the axis of the Earth's rotation. The field strength is about twice as strong near the poles (50,000 nT, nT=neno Tesla, 1 nT=10 ' gauss) as it is near the equator (30,000 nT). This magnetic field is not exactly a dipole field but consists of minute non-dipole components.

Though the Earth's magnetic field is largely dipolar in nature, the two poles north and south are not fixed; rather, they keep shifting. If their positions are averaged over a long span of time, say, a few ten thousands of years, they would coincide with the Earth's north and south poles. The dipole moment of the equivalent substitute magnet also keeps on changing slowly with a maximum rate of about one per cent per year. These changes introduce variation in the direction and strength of the magnetic field at the Earth's surface. This variation is called secular variation.

Fig. 1

The ground-based measurements of the magnetic field of the Earth taken by observatories such as the one at Alibag near Bombay, shown in Fig. 1 here, have been supplemented by measurements taken above the Earth's surface. Fig. 2 shows a magnetometer suspended from an aircraft. Air-borne field measurements, made generally at altitudes of 1 to 5 km, not only make the coverage of inaccessible areas feasible but are also more rapid and cheaper. But to map fields due to sources situated deep inside the Earth's crust whose effects cover larger surface areas, satellites orbiting the Earth about 200 km or higher are ideal. Fig. 3 shows a sketch of Magsat. The satellite's orbit was such that it gave full Earth coverage. Two star cameras helped very accurate determination of the attitude of the satellite. The magnetometers were kept 6 m away with the help of an extended boom to protect them from the magnetic disturbance caused by the star cameras

Fig. 2

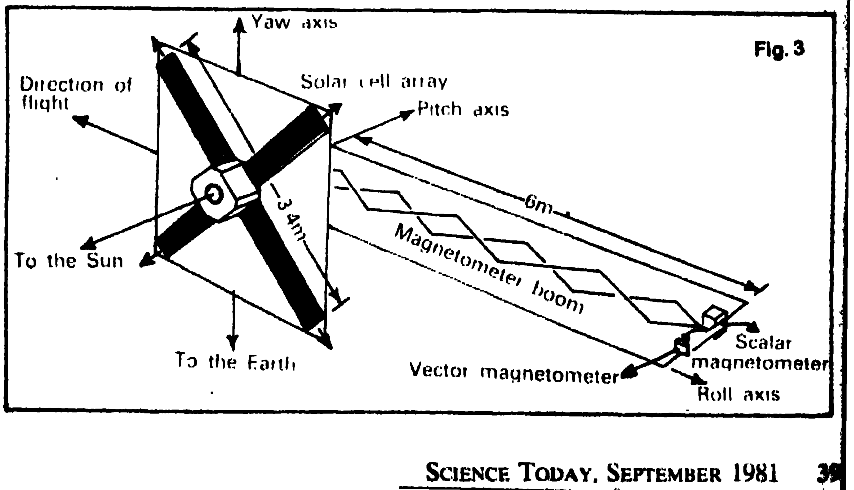
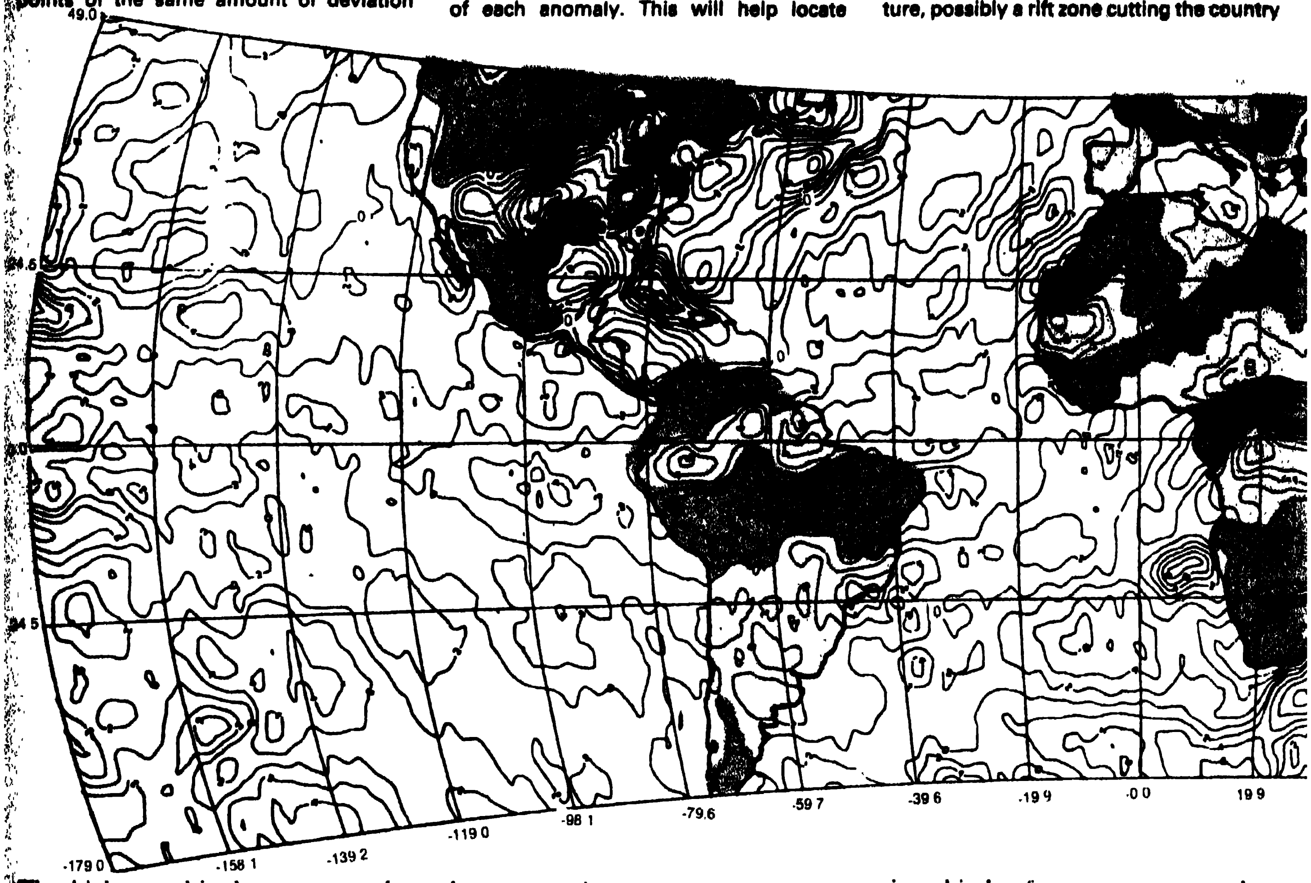


Fig. 3

Fig. [illegible] The crustal magnetic anomaly map between the latitudes +49° and −49° prepared with Magsat data for a height of 347 km. The map was prepared by subtracting a model of the main field of the Earth, called the core field, from the measured field. The contours called isogams connect points of the same amount of deviation from the main field. The contours bearing positive numbers are coloured gray, whereas contours bearing negative numbers are coloured blue. The numbers are in units of nano Teslas. The aim of the map is to determine, along with other geophysical and geological data, the source and cause of each anomaly. This will help locate mineral and oil deposits and [illegible] features that could lead to a better understanding of the forces that shape the Earth. For instance, the important features of the Indian region seen in the map are the Himalayas and the Narmada-Son lineament. The latter is a newly identified structure, possibly a rift zone cutting the country



The higher multipole moments also vary with time and the observed secular variation is the sum of changes in all components.

Superimposed on the Earth's main magnetic field are "magnetic anomalies"—weak fields produced by materials within the Earth's crust. It is known that ferromagnetic materials, such as iron, lose their magnetisation above a certain temperature known as the Curie temperature of that material. With increasing depth, the Earth's temperature increases and the Curie temperature is reached at a depth of about 50 km. So the cause of magnetic anomalies is materials at shallower depths. The magnetisation could be acquired through two ways—induced and remanent. The first is magnetisation produced by the inductive influence of the Earth's magnetic field, similar to the magnetisation of an iron needle rubbed by a magnet; the second is residual, from the past history of formation of the rock. The anomaly map prepared from the Polar Orbiting Geophysical Observatory (POGO) satellite data being scalar (only strength magnitude) in nature could not resolve between the two components. However, the Magnetic Field Satellite (Magsat) data which is vector (both strength magnitude and direction) should be able to separate remanent and induced magnetisations.

The third contributor to the Earth's magnetic field is the external current system. An envelope of charged particles (both positive and negative) surrounds the Earth. The lower end of this envelope, called the magnetosphere, is the ionosphere Due to the interaction of electromagnetic radiation and charged particles emitted from the Sun and the relative motion of the Earth, Sun and the Moon, a complex currrent system is generated in the magnetosphere and the ionosphere. The strength and location of these currents vary a great deal between magnetic quiet and disturbed periods which in turn depend upon the sunspot number.

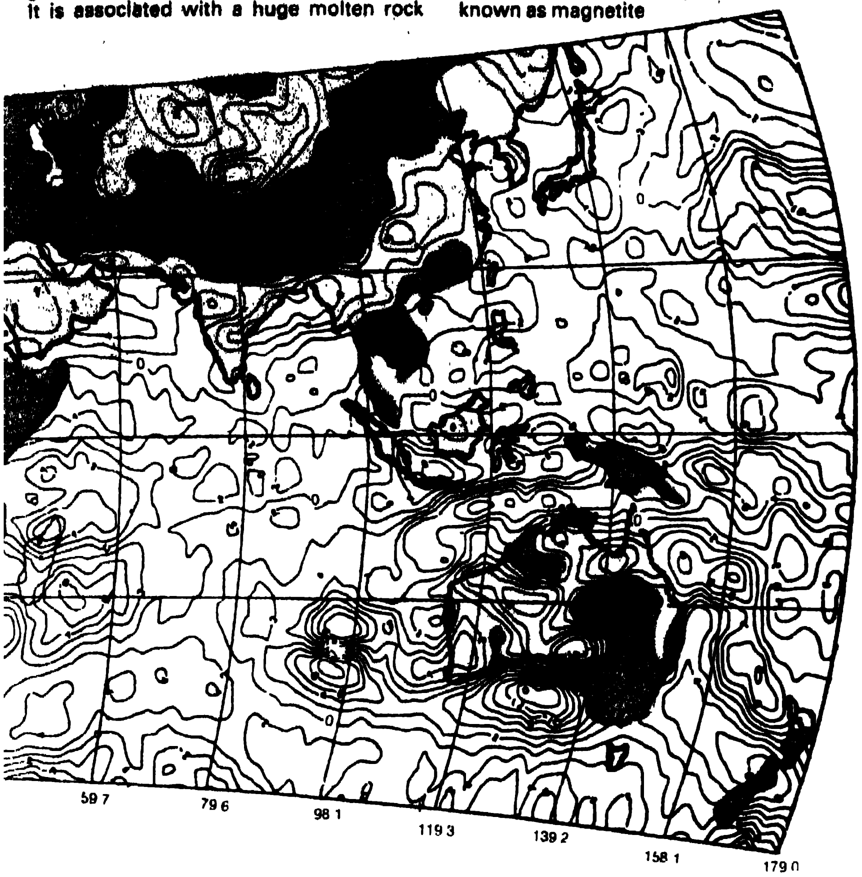
Resource survey

The location of a geological structure in resource survey is very much like locating the criminal in a detective story. The overall exploration problem is to gather clues from various kinds of measurements and to study them together to find the structure common to all. The common geophysical exploration techniques are magnetic, gravity and seismic. They help in estimating different physical properties of subsurface materials. The first is dependent on permeability, defined as the ratio of the intensity of magnetisation and the applied magnetic field, the second on density and the third on elastic properties. Such diverse measurements give information on the geologic structure of interest. The point of interest, however, is that the three surveys do not cost the same and this factor largely guides the order in which they should be undertaken. The cost ratios of magnetic, gravity and seismic survey are 1:10:100. No doubt, results from seismic surveys are most definitive, but its huge cost prohibits its use in reconnaissance work. Normally an explored region is first surveyed through magnetic field measurements.

Around the world, a number of land-based observatories situated at selected sites—for example, the [illegible] to Shillong in Meghalaya. It appears as a line of transition from a positive anomaly on the southern side to a negative anomaly on the northern side over the Himalayas. A very prominent low magnetic anomaly region called *Bangui* anomaly (marked A) is in central Africa. It is associated with a huge molten rock

The magnetic high (marked B) north of Bangui anomaly seem to follow a huge rift which nearly split apart Africa over 180 million years ago.

The top of the map shows a magnetic high (marked C) in the USSR. This area has a large quantity of strongly magnetic iron mineral known as magnetite



observatory at Alibag near Bombay (Fig. 1)—continuously measure the Earth's magnetic field. Since the early 17th century, seafarers have been preparing charts of the strength and direction of the magnetic field for better navigation. With the advent of self-orienting and direction-insensitive electronic magnetometers, magnetic surveys of inaccessible regions could be carried out from airplanes (Fig. 2). Airplane (aeromagnetic surveys) surveys are faster than ground surveys. Aeromagnetic surveys are particularly important for off-shore regions. Potential areas identified from magnetic methods are then studied in detail through gravity and seismic methods. Thus, the cost is considerably reduced and the exploration work also speeds up.

Satellite surveys

The geo-magnetic survey with satellites began in 1958 with the launch of Sputnik 3. It is important to distinguish between the signature of the crustal features (signal) in magnetic data collected from ground, air-borne and satellite-borne surveys. The signal has three components—short wavelength, medium wavelength and long wavelength. The short wavelength is generated by magnetic materials on the very top surface of the crust, the medium wavelength from materials at shallow depths and the long wavelength component from deep-seated structures. The ground data contain contributions from all sources, the air-borne data contain only medium and long wavelength components and the satellite data contain only the long wavelength component. In the context of exploration of resources at exploitable depths, the ground data offer the largest information content, and then air-borne data; for an exact calculation of the structure, the long and medium wavelength components from ground and long wavelength from aeromagnetic data must be subtracted. In that sense, results from satellite observations when available for the explored area make the results from ground or air-borne surveys more accurate and meaningful.

A number of satellites measured the near-Earth magnetic field but with the launch of Magsat by NASA a new era was ushered in. Magsat was launched on 30 October, 1979 and was back on Earth on 11 June, 1980. Though the US Geological Survey and NASA were the principal users of the Magsat data, other investigators from the USA, and eight countries, including India, participated in the programme. The satellite altitude varied between 325 and 575 km. Besides measuring the strength of the field, it also measured its direction. This directional characteristic of the measurements made the data sent by Magsat very useful for crustal studies. Other special features of Magsat (Fig. 3) were: (i) a Sun-synchronous dawn-to-dusk orbit to reduce ionospheric components in the measured field; (ii) star cameras to accurately estimate the altitude; and (iii) good altitude determination.

How are the space-borne magnetic field measurements deployed to locate mineral deposits and to unravel the Earth's mysterious past? The first step in crustal studies using space-borne magnetic field measurements is to isolate the component of crustal origin from total field measurements as the field measured by instruments on a satellite is a sum of the main field arising from currents in the core of the Earth (or core field), the field arising from magnetised areas in the crust (called anomalous field) and the field arising from external currents in the ionosphere and magnetosphere. A major problem in this exercise arises from the fact that the measurements are being made from a fast-moving spacecraft in a continually changing orbit. Another problem is the very nature of the Earth's magnetic field which is in a state of perpetual disturbance arising from the complex interaction of solar-wind particles and the Earth's magnetosphere. Also, it becomes difficult to separate spatial variations from the temporal disturbances in data collected with a moving vehicle.

Strengthwise, the main field is about 40,000 nT, the crustal component and the components from external currents are of magnitude ranging from tens of nT to a few hundreds of nT, depending upon time and spatial position. In Magsat data the ionospheric component is considered to be small as the satellite was placed in a Sun-synchronous dawn-to-dusk orbit. Only those days would be selected, which were geomagnetically quiet —undisturbed by solar activity—thereby producing very small variations due to external currents. After removal of core and external field contributions, the residual would give the anomalies.

The global map of the distribution of magnetic anomalies between the latitudes +49° is shown on pages 40 and 41. The map can be used to study the magnetic properties of the largescale crustal regions of the Earth. Interesting features in the map can be picked up for more detailed studies. Through a joint analysis of anomalies in the magnetic field, gravity field, heat flow, etc and from the imagery of the crust, the geologically significant features of regions measured in hundreds or even thousands of km can be known. Once zones are identified and characterised on a global basis, they should provide useful information regarding the dominant forces and movements that shape the Earth. They will also help delineate segments of the crust into resource provinces which will lead to an assessment of the mineral resources of a region or of a country. So the most promising areas for future mineral exploration can be identified and it will be possible to determine even the exploration strategies.

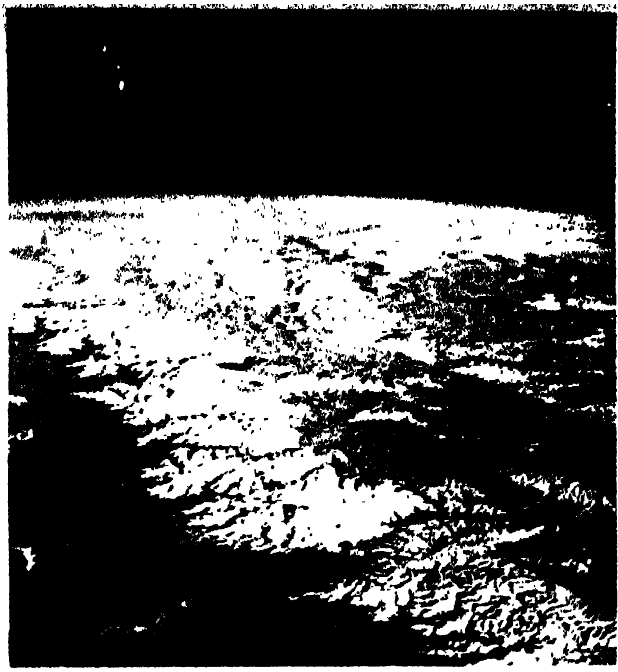


Fig.5. One of the sources of low magnetic anomaly could be a region experiencing intense plate tectonic activity. An example is the Himalayas shown in this photo taken by Apollo 7 spacecraft. This mountain range is supposed to have formed due to the slamming of two huge crustal slabs of the Earth

The map shows that a steep rise and fall is a unique feature of the Indian region. This could be due to the fact that the region is still tectonically active. We notice a magnetic low over the Indian Ocean—being zero below the tip of the peninsula—attaining a maximum value over the peninsular region, again becoming zero near the Narmada-Son lineament. The Narmada-Son lineament runs from 21°N, 71°E in the west coast of India to Rajmahal Hills. Observations indicate that it could be associated with a rift-like structure buried deep under a thick layer of sediments. The continuing cyclic variation becomes a low over the Himalayas. These patterns are also present to a significant extent in gravity anomalies and *subcrustal stresses* computed for the Indian region. The fact that these patterns are seen at satellite heights indicates their deep-seated origin and a modelling of these data may provide some unique information on the structure of the Earth's interior below India and on geodynamic processes. It is well-established now that tectonic processes that contribute to the dynamics of the Earth's crust (that is, plate motion, earthquakes, volcanism, and mineral formations) are related to the processes that originate in the mantle and core

Scientists from the Indian Institute of Geomagnetism are preparing a regional geomagnetic reference field and magnetic anomaly maps over India and its neighbouring areas with the help of Magsat data. They are also studying in detail the transient variations in the magnetic field. By comparing magnetic data with gravity data from Geos-3, Robert F. Brammer of the USA is investigating Eastern Indian Ocean area. Igor I. Gil Pacca from Brazil is using Magsat data to study the structure, composition and thermal state of the crust in Brazil. Recently huge diamond deposits have been found in the Amazon basin which unlike the diamond deposits in Africa are not associated with a mineral called kimberlite. In Africa kimberlite is found exclusively in regions of low magnetic anomalies. It will be interesting to investigate the various combinations of geological causes which are responsible for the formation of diamond deposits. Paolo Gasparini of Italy is calculating, for the Mediterranean area, the depth of Curie temperature which indicates the depth of magnetic crust beyond which, because of high temperature, all material is nonmagnetic. He will relate it to areas of volcanic activity. Some of the magnetic anomalies may be associated with regions having a thin magnetic crust from which heat flows out of the Earth's interior.

An important mission objective of Magsat is to compute an accurate description of the Earth's main (core) field. This objective is as important as the crustal studies—basically because the accuracy of one depends upon the accuracy of the other. Development of a good model for the main field will contribute to: (i) a more accurate magnetic field, which is often needed, in ground, sea or air-based magnetic surveys in geophysical prospecting, (ii) an accurate separation of the main field to isolate components originating from ionospheric or magnetospheric current systems, and (iii) the study of the Earth's core and core-mantle boundary. While previous POGO data were unable to give a good representation of the model field as the measurements were only scalar in nature, the Magsat, with vector measurements, will provide adequate data to develop a good model.

The magnetic data have other uses also. For instance, they can help study the question, is the Earth heading towards another magnetic field reversal? The preliminary phase of the analysis of Magsat data by R. A. Langal and his co-workers at the Goddard Space Flight Center (USA) showed the continuing decrease of the strength of the Earth's dipole magnetic field at a rate of 25 nT per year. If this rate of decrease continues, the Earth's field would reverse in about 1,200 years. We do not know enough either by laboratory or theoretical experiments to forecast the change of the Earth's magnetic field. Core dynamics is complex, because it is unseen and speculative, because we can only imagine what happens there and perhaps it "attracts" us because we do not know it at all.

Prof. Singh is with the Indian Institute of Geomagnetism, Bombay. He did MSc from Bihar University and PhD from Queen's University, Kingston, Canada. His main research interest is the use of variations in geomagnetic field in studies of the Earth's interior.

Fuel-rich pockets give more efficient spark-ignited engines

THE spark-ignited petrol engines fitted on to most motor cars invariably have a lower thermal efficiency than diesel engines, which drops still lower when they run at partial loads (below 40 per cent of their rated power). The reason is the way they draw their fuel. The carburettor admits the air and fuel mixture and throttling it controls the power. The problem is that at partial loads the mixture put in has to be much richer in fuel for effective spark ignition. The lack of enough oxygen in the mixture means that part of the fuel is wasted because it does not burn. Charles Goodacre, a British consulting engineer, has designed an engine which tries to take care of this problem with a separate combustion chamber—almost an external combustion engine *(New Scientist,* **89,** 1240, 412).

It is possible to work an engine at partial loads on a lean mixture if we could somehow create a pocket of rich mixture enveloped by the lean mixture. The rich mixture pocket could then be ignited ensuring complete combustion of the entire mixture and a good thermal efficiency. The creation of such a heterogeneous pocket, technically called charge stratification, is quite easy in diesel engines. Diesel engines are compression ignited, that is, the air is compressed to such a degree that the compression itself is sufficient for ignition. In such engines pure fuel is injected and a fuel-rich pocket can easily be formed. Charge stratification, however, is not easy for spark-ignited petrol engines. Goodacre's design tries to do just that.

In the cylinder head casting, Goodacre incorporates a *spherical* combustion chamber, a shape accepted as ideal for a combustion chamber. A sparking plug with a long central electrode sparks on to a bar made up of Nimonic 90 alloy and placed at the centre of the chamber. A short, broad passage connects the chamber to the cylinder. Fuel under pressure is injected through a nozzle with two holes and hits the bar and atomises. Air entering during the compression stroke sweeps the fuel mixture around the bar. Fuel injection is so timed that all the combustion is completed in the chamber.

The air flowing around the bar and the fuel injection system give rise to an "Einstein vortex". The larger droplets stay nearer the bar because of their higher weight and inertia while the smaller, lighter droplets move away to the outside of the vortex. This creates just the fuel-rich pocket needed for charge stratification around the bar and the spark ignites this pocket. The flame burns radially outward but because the mixture is lean, combustion is complete before it reaches the chamber wall. The residual air forms a shell between the burnt fuel and the chamber to minimise heat loss.

Though much like a diesel engine, Goodacre's design retains spark ignition. Also, unlike a diesel engine, the combustion does not continue into the cylinder. The passage from the chamber to the cylinder has, however, to be accurately designed. It has to be broad enough to allow sufficient air to flow through it during the compression stroke. If it is too long, too much fuel is consumed, if too short the piston is damaged by the hot gas.

Goodacre's innovative design follows in a long line of research on charge stratification starting way back in the 1930s. So much work has gone into the basic design that the scope for innovation has narrowed considerably. In view of this, Goodacre's design is a good graft of some features of a diesel engine on a spark-ignited petrol engine.

Commercial application of Goodacre's design on a large scale, however, is not likely, especially in India. Firstly the injection equipment required makes the engine costlier. Secondly, if fuel injection systems have to be used then why not go in for the full diesel engine? It may be somewhat more bulky but its higher compression ratio will also give a higher thermal efficiency. Goodacre's engine may find better use if, as he says, it can be run on a wide range of fuels from gasoline to diesel oil and even alcohols without adjustment of its fuel injection system.

There is, however, one possible area for which it may be worth considering in India. The manufacture of two-wheelers is on the increase and two-wheeler petrol consumption will further strain scarce petrol supply. Cars are likely to go diesel but the two-wheelers cannot change to the bulky design. So, even with the design change and expense involved, the use of an efficient spark-ignited petrol engine in two-wheelers may be a point to consider.

K. A. K. SUNDARAM

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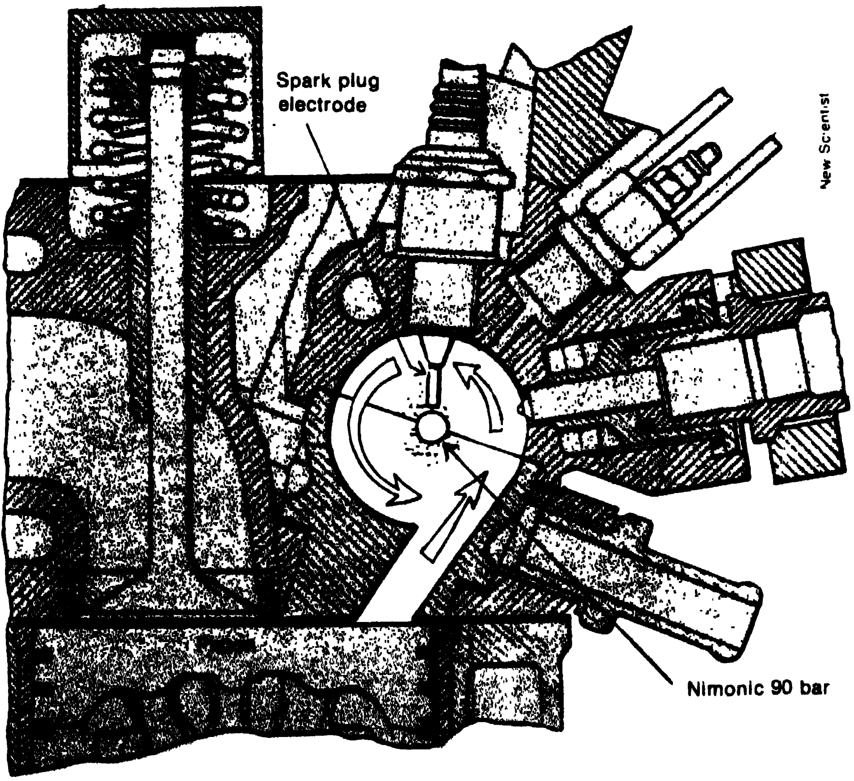


New Scientist

Creating a fuel-rich zone with a separate combustion chamber increases efficiency. Goodacre's design shown above has a separate combustion chamber (unshaded portion) connected to the cylinder head. Air entering during compression stroke (arrows) creates a vortex, which makes smaller fuel droplets fly outward, creating a fuel-rich pocket near the ignition spark, ensuring complete and efficient combustion even with lean mixtures

Bullock cycle for increased speed

THE speed of a conventional bullock cart is limited by the speed of the bullocks. Most design modifications suggested for the bullock cart have operated within this constraint. B. Shankar Sharma, of the Cost Engineers' and Procurers' Association, Bombay, has now suggested a novel idea of a bullock-cycle, that does away with this limitation.

Shankar Sharma's design, on his own admission, is at present a very rough one and purely hypothetical. His arrangement is much like a cycle-rickshaw with the bullock replacing the man. There are, however, two pairs of pedals for each bullock. Each pair of front and rear wheels is provided with pneumatic tyres. The bullock is to be supported by a semi–cylindrical shaped seat with straps on one open edge to be lashed to the other open edge.

Shankar Sharma mentions a braking system and steering mechanism but these are not shown in the rough diagram. Presumably they are of conventionally available design. He provides for unidirectional rotation of pedals corresponding to a forward motion of the cart. The possibility of the animal's hoof slipping from the pedal is taken care of by a housing. Dual purpose brakes are also proposed which disengage the pedals from the transmission system when the brake is applied. This is to protect the animal from the load of sudden braking.

Whether the idea will be feasible and what modifications are needed for this are questions that can be answered only after deeper study and, above all, field trials of prototypes. The very first point, which will have to be investigated is whether the bullock can provide the required pedalling motion, and the ease with which it can be trained to do so.

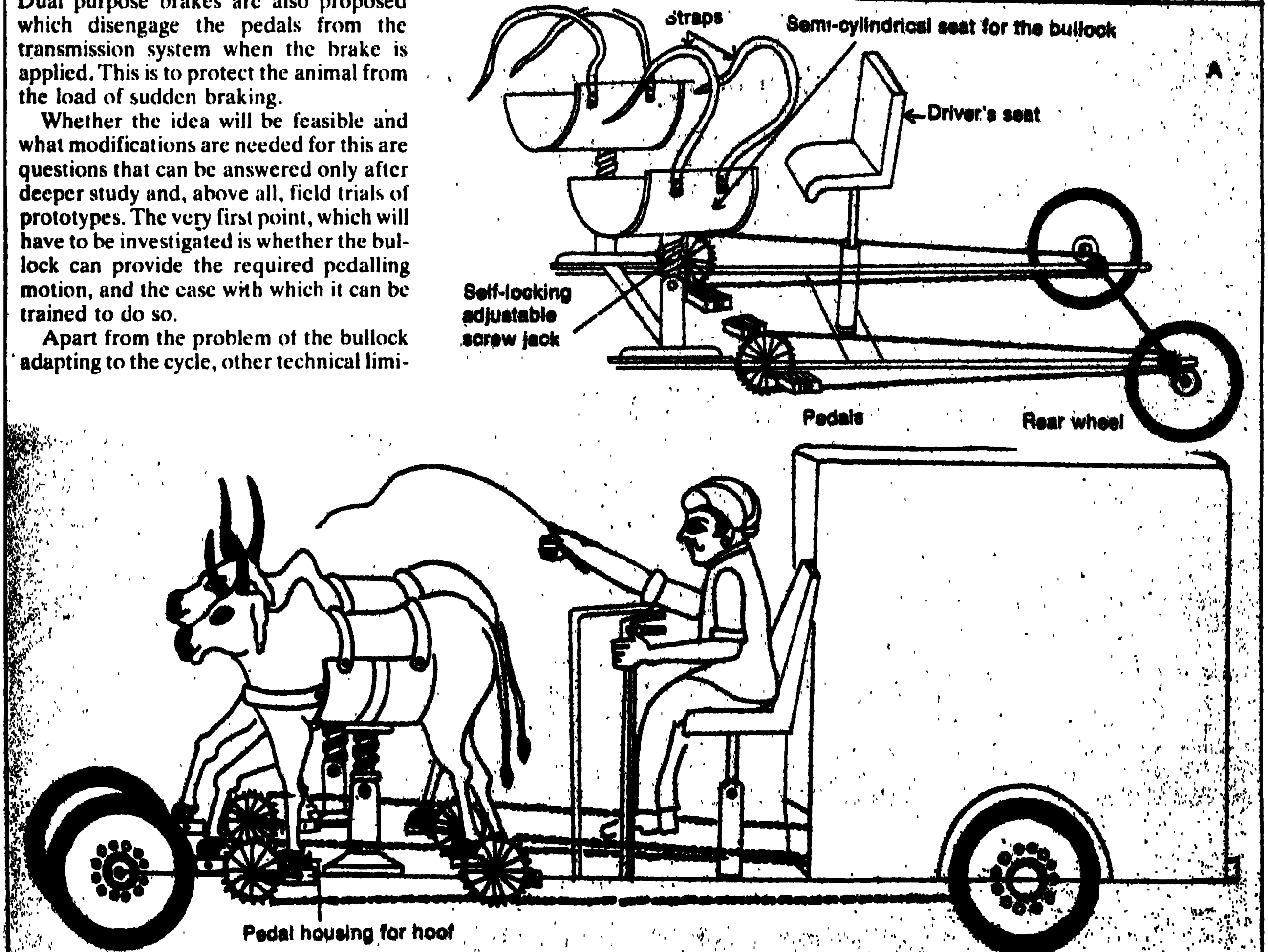
Apart from the problem of the bullock adapting to the cycle, other technical limitations will have to be studied. Bullock carts are conventionally used for transporting heavy loads of up to 1,000 kg (Shankar Sharma proposes a capacity of 1,500 kg) at low speeds. Once the speed is increased, the tractive resistance will definitely have to be taken into account. Unless it is lowered considerably, the load carrying capacity of the cart will be curtailed in almost the same proportion as the increase in speed. The terrain will also present problems.

Perhaps, a cycle design along these lines may be more useful for the other crushing or lifting devices, like drawing water or extracting oil from seed, which Shankar Sharma mentions in passing.

S. KRISHNAMOORTHY

A. S. MENON

Dr. Krishnamoorthy and Mr. Menon are both Professors in the Department of Mechanical Engineering, Victoria Jubilee Technical Institute, Bombay.


Straps
Semi-cylindrical seat for the bullock
A
Driver's seat
Self-locking adjustable screw jack
Pedals
Rear wheel
Pedal housing for hoof

Schematic view of Shankar Sharma's bullock cycle. Some of the details are shown at A. The bullock cycle, operating much like a cycle rickshaw, need not limit its speed to the speed of the bullocks

Horse-powered minibus

IN the bullock-cycle (see alongside), the bullock pedals on and on, never coming in contact with the road. Philip Barnes of March in Cambridgeshire, UK, now extracts energy from a horse which walks on and on inside a minibus without even coming into contact with the road (*New Scientist*, **91**, 1262, 153).

The minibus, which seats five and a driver besides the horse, has an endless, free-running, looped, conveyor belt connected to a gear box and an alternator. The horse walks along on the conveyor belt to charge the vehicle battery and the driver steers the vehicle.

The details of the contraption include a thermometer under the horse's collar with the temperature displayed as a digital read-out on the minibus instrument panel to check "overheating" the horse. A mop connected to a manouverable pole can be waggled to start the engine. A food box mounted under the head allows the horse to "recharge" itself. And, of course, passengers are protected, by two sloping panels that box in the horse.

P. V. PARANJAPE

Mr. Paranjape is on the editorial staff of SCIENCE TODAY.

BOOKS

Milestones in planetary physics

[illegible]

THE past decade has brought the solar system within the reach of experimental science, and planetary physics has moved from the realms of guesswork to those within solid physical foundation. Yet, the spectacular technological successes of the space missions and the high drama associated with remote control, pin-point accuracy and split second timing have overshadowed the *scientific* achievements such that "it is passing almost unnoticed by the public at large". The gap between discoveries and public awareness is widening with space missions becoming a routine affair. *The Planets* goes a long way to bridge this gap.

Written in a lucid style, the book covers, in historical perspective, the major milestones in planetary physics culminating in the most recent findings. It devotes a chapter each to the Moon, Mercury, Venus, Mars, Jupiter and Saturn and the outer planets with special chapters for the Apollo and Viking projects. Two-thirds of the book is devoted to the inner planets and rest to the outer solar system. The author discusses the atmosphere, surface features, internal structure and astronomical statistics of each planet, illustrating the major points by pictures and sketches. A chapter on minor planets—meteorites, asteroids and comets—and another on the synthesis of ideas give a rather complete view of the solar system. This book thus makes informative reading both to people with general interest in our celestial neighbours and to students of planetary physics who want to have a quick glimpse of the solar system.

The similarities observed on the Moon, Mercury, Mars and Venus have brought to light the common links that existed in the inner solar system during the formative stages of these bodies. The Moon and the Earth form the two end members of this sequence, and both these are now the best understood of all. A comparative study of the inner planets indicates that the basic law of planetary evolution is governed, to a first degree, by the mass of the planet and volcanism, plate tectonics, and frequency of craters, etc indicate the extent of the planetary evolution.

In spite of these superficial similarities, each planet is unique. Venus, the romantic queen of the solar system, is in fact as hot and unlivable as hell with rains of sulphuric acid pouring on the red-hot rocks from the thick carbon dioxide clouds above. The high hopes of finding life on Mars or elsewhere have been frustrated, and Saturn has shown more rings than one cares to count. The discovery of pre-solar grains in a meteorite which fell in the jungles of Mexico tops them all and has brought into focus the possible mechanism by which the solar system formed. The book contains a vivid description of many of these important findings.

In spite of the wealth of new findings described, the book has not been able to keep pace with the planetary *exploration* The chapters on Jupiter and, particularly, Saturn are out of date even as the book came out of the press. As a result of the Voyager fly-by of Saturn, the basic concepts of Saturn's rings, its satellite dynamics and even the general perspective of the outer planets have changed. Two more satellites of Jupiter (there are now 16) and at least four of Saturn (now 15) have been discovered since the book was written. Further discoveries await the Voyager 2 fly-by of Saturn in August 1981 and of the outer planets in the near future. Of course, the author expresses his awareness of these limitations, inherent in the rapidly advancing field of space exploration, and has done a good job of the material available when the book was being written. These drawbacks do not however limit the usefulness of the book significantly, as the 400 pages take one's imagination through the breadth of time and space. In general the book is a welcome addition and will serve as an introductory work covering different aspects of planetary physics, chemistry, geology and meteorology.

The discoveries of the past few years will certainly have a profound impact, not only on our ideas of the origin and evolution of solar system but more importantly on human psychology and social behaviour in which "stars" and the unknown have played a key role. The book should go a long way in dispelling myths about various objects in the solar system which are still popular, but which can now be replaced by scientific facts.

N. BHANDARI

Prof. Bhandari, whose major research interests have been meteorites and Moon rocks, is with the Physical Research Laboratory, Ahmedabad.

Of management and engineering

[illegible]

THE concept of productivity—the organisation of men, materials, machinery and management to the best possible advantage to the society—is of comparatively recent origin. The awareness is that this idealisation be applied more and more not only to the day-to-day industrial applications, but also to any long-time proto-social planning. The book is a useful contribution to a complex problem of social education and creation of public awareness on the problems of productivity.

Productivity, as the word implies, is a dynamic process in the sense that the controlling parameters change with time and many other variables. The book deals with a number of themes covering financial, engineering and human aspects and gives information about measures which are accepted. In addition to the why's, a prospective entrepreneur or organiser seeks answers to the how's—he has to find answers in his own environment. As one carefully glances through the contents, one finds a list of diversified topics from management science, like scales realisation, profits management, maintenance, personnel management; from industrial engineering, like production, value engineering; and from management philosophy things like innovation, and perspectives of management. The presentation of the subject is certainly very lucid and the author gives an appreciation of the difficulties experienced in taking management decisions. There are a number of non-Indian authors who have discussed these issues in a wide range of published literature. But here are other interesting features, like waste reduction, fire control, industrial safety and other associated issues which will be better appreciated as productivity improvement measures.

The statistics given are very live and effect producing. The discussions involve many aspects related to the chemical industry, for instance, cement, fertiliser, caustic soda, sulphuric acid and rubber. The delineation made here to support many basic productivity concepts will be important for practising engineers.

Although it appears to have been written with chemical engineering personnel in mind, the book could make very interesting reading for students and research workers in applied economics as well.

Y. K. DANGE

Prof. Dange is with the Department of Mechanical Engineering, Indian Institute of Technology, Bombay.

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ENVIRONMENTAL SCIENCE AND POLICY IN CHINA

Baruch Boxer

Most of China's environmental research is linked to specific economically important projects

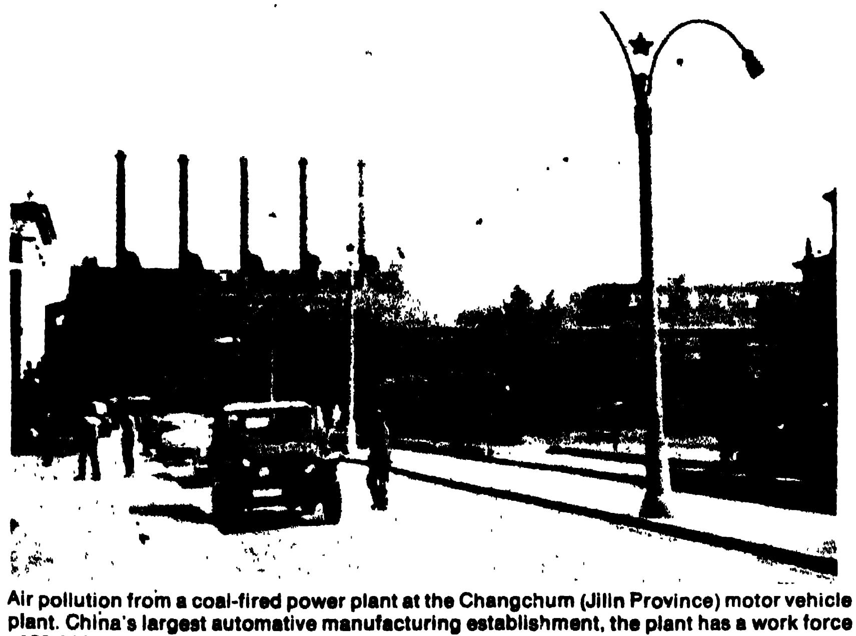
It has been suggested that the longevity of Chinese civilisation can be attributed partially to sound environmental practices. Systematically defined responsibilities and limitations in relations between man and nature were described as early as the first century B.C. These notions provided a natural philosophic rationale for environmental stewardship, which, despite some local and regional abuses, prevailed through the centuries. Since China represents perhaps the most illuminating example of the successful historical evolution of workable strategies for sustained productive use of human and natural resources, any attempt to characterise present-day environmental activities cannot overlook pre-modern contributions.

Briefly, historical concern for the environment is reflected in the Chinese genius for water management—their ability to conserve minute amounts of moisture and distribute large volumes of water for irrigation; in their energy budgeting and waste recycling for maintaining the agricultural ecosystem; in their definition and application of environmental and landscape planning principles (codified in the *feng-shui*, or geomancy, locational belief system); and in their use of cartographic and topographic analysis in the context of hydraulic engineering to conserve soil and water.

Another unique approach to environmental conservation can be seen in China's historical success in developing clusters of urban and rural communities that supported large populations while adequately maintaining ecological integrity. Some of China's most innovative and comprehensive post-1949 attempts to deal with pollution and environmental management problems are built to some degree on traditional interests and skills.

While Mao was not especially sensitive about the environment, his writings showed traces of the influence of Marx and Engels, who did anticipate some elements of modern ecological theory. In his classic essay "On Contradiction", for example, Mao provided a theoretical basis for later ideological endorsement of environmental protection efforts.

In China, environmental science has no clearly defined disciplinary foundation and is diffuse and uncoordinated. It includes work in many areas of the physical and biological sciences, particularly chemistry; biomedicine, and theoretical and applied branches of engineering. Recognition of the discipline of "environmental science" and emphasis on environmental research are fairly recent phenomena. Until 1978, when the first journal on environmental science, *Huanjing kexue* (Environmental Science), began publication in Beijing, pertinent information was sparse and scattered.



Air pollution from a coal-fired power plant at the Changchum (Jilin Province) motor vehicle plant, China's largest automotive manufacturing establishment, the plant has a work force of 35,000. According to plant officials, precipitators had been installed in three of the stacks as of May 1980. (All photos in this article courtesy of Baruch Boxer)

Environmental policy

China only recently recognised the need for a cohesive national environmental policy. This does not mean, however, that China was not taking measures that benefited the country's environment, but simply that all too often environmental gains were by-products of other goals and policies more directly related to major national priorities.

For the first two decades of the People's Republic, environmental concern focused on improving the living conditions of the Chinese people. There were almost perpetual health campaigns—mobilisation of the masses to eliminate "the four pests" (flies, mosquitoes, rats, and sparrows)—and educational campaigns regarding sanitation and safe methods of using human excrement as fertilizer.

In the late 1960s a major national campaign calling on the Chinese population to "transform wastes into treasures" and to recycle and recover the "three wastes"—liquids, gases, and solids—was launched. This policy combined Mao's principles of self-reliance and frugality and at the same time made environmental protection and conservation a concrete responsibility of the "worker masses"

Mao's policy of industrial and urban dispersion was primarily inspired by security concerns and economic and social considerations, but it also served environmental protection objectives, since pollution is normally a direct reflection of population densities. By controlling the growth of major cities and building small rural industries, the Chinese

Locally designed ion-exchange waste-water treatment system at Guang Ming electroplating factory in Shanghai. Flowers growing outside the plant are unaffected by the fumes associated with the process

the less obvious but geographically more extensive degradation problems stemming from resource development.

In 1974 H.Y. Yan identified five pollutant categories that should be studied:

- industrial wastes such as sulphur dioxide, hydrogen fluoride, heavy metals, cyanide wastes from electroplating, suspended materials from paper, fibre and foodstuff manufacturing, and radioactive wastes;
- oil and petroleum hydrocarbons;
- toxic substances in pesticides, food additives, and other daily use and industrial items;
- toxic products of naturally aged or transformed materials like rubber and plastics;
- bacterial and viral organisms in domestic sewage.

In 1979 research focused only on studies of natural cycles of groundwater, surveys of effluent quality, analyses of drinking water and human blood for trace-element contamination, and catalytic reactor development. Chinese scientists are, however, becoming more sophisticated in both applied and process-related studies of the causes and effects of pollution.

Water pollution

The major focus of China's environmental effort during the past decade has been (and undoubtedly will continue to be) the maintenance and improvement of water quality. Those industries in which the greatest attention has been paid to pollution control are iron and steel, oil and petrochemicals, metallurgical, chemical fertiliser, plastics, synthetic fibre, and paper and pulp.

Some of the most effective applications of research along these lines have been carried out since the early 1970s by the Dalian Institute of Chemical Physics in coking and dyestuffs plants. The Haerbin Architectural Engineering College's Water Treatment Research Laboratory has applied methods for recovery of waste acid and ferrous sulphate, and used electrolysis, evaporation concentration, and ionic exchange in treating waste water from metal fabrication industries.

For new iron-and steel-manufacturing facilities, there is some evidence of control systems being imported along with the plants, since Japanese manufacturers have sold steel mill drainage and disposal systems to China. Until 1976, however, application of indigenous technologies had been the common practice.

The Daqing oil field in Heilongjiang province, China's largest, is a good example of the integrated development of pollution control and material-recycling facilities in a complex of extractive and fabricating industries. Since the opening of the oil field in 1960, conservation and treatment of domestic and industrial waste-water have been co-ordinated. By the mid-1970s, 16 primary and secondary treatment plants were in operation, and it was reported that in the period 1970-1976, 300,000 tons of crude oil were recovered from refinery effluents. Processes for treating sulphur-containing refinery effluents included oxidation, the use of copper chloride as a catalyst for low concentrations of sulphur, and steam stripping at high temperature and pressure, which permits recovery of hydrogen sulphide and ammonia. Active carbon absorption purifiers have also been used to treat refinery effluents for recycling.

Similar examples could be cited for the chemical, paper, and fertiliser industries. The most cost-effective and technically efficient examples of combined control and recycling shared two common features: application in industrial settings close to research institutes or academic research units and application in new plants or plants rebuilt in connection with the development of integrated urban-industrial-agricultural complexes. H. F. Yang's work at the CAS Institute of Microbiology in applying sophisticated techniques to treating polyacrylonitrile wastewater from synthetic fibre plants is a noteworthy example of fruitful co-operation between laboratories and technologically advanced industry.

Useful and environmentally relevant research has also been carried out on problems of quality maintenance in underground water storage schemes and in the design of water purification plants capable of discharging and treating effluents for agricultural use.

Air pollution and wastes

In contrast to water pollution, air pollution research has received relatively little attention in China. And yet because of the predominant use of coal for domestic and industrial purposes, urban air pollution is severe. Given China's limited capability for widespread installation of modern air pollution control devices, the prospects for reduction of unacceptably high levels of sulphur dioxide, nitrogen dioxide, and particulates are poor.

There is little evidence of any

Recycling container at the Changchun railroad car plant. The characters on the bin mean "steel scrap." Mao's principles of self-reliance and frugality have long directed industrial workers to conserve and recycle on the job.

Environmental research

As of the late 1970s. Chinese notions of the purposes and objectives of environmental science and technology reflected:

- a continuing interest in comprehensive approaches to conservation and management of soil, water, mineral, and material resources;
- concern for protection of natural areas and endangered plant and animal spedcies;
- acknowledgment of the urgent need for scientific and technical work to ameliorate the harmful effects of industrialisation on ecological systems and on human health; and, of course,
- the application of Marxist ideas of the social and economic value of environmental protection.

Environmental research is also seen as contributing to the nation's ability to derive economic rewards from frugality in resource use during a period of rapid economic expansion.

As has already been pointed out, many scientific disciplines touch on problems involving the study of environmental processes or on the nature and effects of environmental changes on plants, animals, or man. It is difficult, however, to find references to common methodological or theoretical approaches that integrate disciplinary work into a coherent, preconceived "environmental" framework.

Since the early 1970s, references to the mission and objectives of environmental research and descriptions of work in various disciplines have made subtle but, in the Chinese context, important distinctions between "protection of the environment" and "pollution control problems."

Generally speaking, the disciplines primarily supportive of "protection" objectives include plant and animal ecology, botany and geobotany, environmental geology, geography, hydraulic and civil engineering, and geochemistry. Those disciplines that are identified in the literature with what the Chinese call "control" objectives are hydrobiology, analytical (or pollution) chemistry, chemical engineering, microbiology, and soil science.

Although public health improvement is frequently mentioned as an objective of environmental research, the environmental health sciences are not usually referred to in the scientific literature as environmental sciences per se. This is an important distinction, especially with regard to the criteria employed in environmental standard setting.

It is important to note, however, that environmental researchers seem to be encouraged to bridge the implicitly acknowledged "protection-control" dichotomy by pursuing research that explores new areas beyond accepted disciplinary boundaries. This has led to innovative work on moisture budgeting, water balance, composting efficiency, pesticide removal from soil and plants, and other problem areas, many of which build on traditional methods and technologies. This is not to say that "interdisciplinary research" in the Western sense is being encouraged. The Chinese approach seems to draw on existing strengths without worrying about overlap and the problems of theoretical communication and methodological inconsistency associated with interdisciplinary work as we know it.

The only Chinese Academy of Sciences (CAS) institute with an environmental designation is the Institute of Environmental Chemistry in Beijing. Other CAS institutes that sponsor research on environmental protection of control are the Institutes of Botany, Chemical Physics (Dalian), Entomology, Geochemistry, Geography, Geology, Meteorology, Microbiology, Plant Physiology, and Zoology. Some institutes, such as Geochemistry and Geography, have bureaus or departments specialising in environmental research.

Environment-related work also takes place under the aegis of many institutes in the agricultural, engineering and technical, medical, and life sciences, and in the provincial-level environmental research institutes mentioned earlier. The Shenyang Research Institute of Industrial Hygiene, for example, has been conducting experiments since the mid-1960s to improve air quality in factories.

A 1978 article in the new journal on environmental science implicitly distinguished between environmental protection and pollution control. Environmental protection research assumes that man is only one element in the natural world, subordinate but not necessarily passive. It serves to illuminate the effects of landscape modification (such as water conservation, land reclamation, mining, afforestation) on man's health and well-being.

Environment, in this research context, is roughly equated with nature. The main emphasis lies in trying to understand, predict, and manage the social, health, and related physical and biological effects of large-scale engineering projects, such as the planned diversions of Chang Jiang (Yangtze) water to the north or the alteration of natural habitats in north-eastern and south-western China in connection with mineral exploration and exploitation and hydropower generation.

Research on pollution control, on the other hand, aims at management of problems arising directly from human activities, such as elimination or neutralisation of harmful substances introduced into the environment.

In general, it seems that China's allocation of research support and personnel for environmental science research reflects far greater concern with the short-term effects of localised air and water pollution than with some evidence to suggest that the best administrative integration of environmental research and control exists in major industrial regions. In Jilin province, for example, by-product recovery and multiple-use procedures were apparently used in most large industries by 1974.

China's institutional matrix for environmental protection was augmented in the mid-1970s by the establishment of small (15 to 20 persons) environmental bureaus (headed by deputy ministers) in each ministry concerned with manufacturing and resource development (including Public Health, Metallurgy, Public Security, Agriculture, Forestry, Light and Heavy Industry, and Transportation and Communications). In the industrial ministries, the environmental bureaus were made responsible for pollution control in government-owned plants.

Other environmental research bodies that were instituted in response to the 1973 directive included a number of institutes affiliated with provincial and municipal governments to study local or regional problems, a few research units in industrial ministries, and some university research groups. Few details of the administrative and policy-making links among these organisations are available. The 1973 directive also called for the development of environmental science curriculas in colleges and universities and a national environmental research institute; but formal education and training in environmental science continues to be based, for the most part, in individual disciplines. However, since 1979 there have been efforts to foster a high level of both scientific and popular interest in environmental science and policy.

In keeping with the new Chinese emphasis on scientific development and communication, many new scientific societies have been formed. Among these are the Environmental Scientific Society and the Ecological Society. The main purpose of these societies is to foster communication through conferences and meetings, and through publications.

Thanks to the formal endorsement of environmental protection by the central government, EPO is apparently now assuming a more substantive policy-making role. In a report to the Fifth National People's Congress on 26 February 1978, Chairman Hua Guofeng called for "elimination of pollution and the protection of the environment [as] a major issue involving the people's health, an issue to which we must attach great importance". He also called for "regulations to protect the environment" and to "make sure that related problems are satisfactorily solved".

Further commitment was indicated by the inclusion of the following clause in the new constitution adopted on 5 March 1978: "The state protects the environment and natural resources and prevents and eliminates pollution and other hazards to the public."

These general pronouncements were amplified in Vice-Premier Deng Xiao-ping's opening address at the March 1978 National Science Conference. Environmental concerns were mentioned first in connection with agriculture, where "national exploitation and utilisation of resources" and "protection of the ecological system" were advocated. The multipurpose utilisation principle, with particular emphasis on the role of science and technology in helping to realise the benefits of recycling and by-product use, was also reaffirmed. Finally, "environmental protection" was designated as one of 27 "research spheres" to be pursued as part of the 1978-85 outline plan for the development of science and technology.

Continued concern about environmental protection is reflected in Hua's June 1979 report on the work of the government to the National People's Congress, in which he mentioned work on an environmental protection law that was promulgated in September 1979. He also stressed the need for "taking environmental protection into account in the construction of new projects". Hua further stated that "pollution problems caused by existing enterprises must be solved step by step." Two other laws with important significance for environmental protection are the Forestry Act (adopted in principle by the National People's Congress in 1979) and the Aquatic Products Law, which protects waterways, fisheries and aqua-culture.

To a large extent, the success of the new emphasis on environmental protection will depend on Beijing's ability to set and enforce environmental standards—until now a serious weakness of the programme. Since the early 1970s, industrial standards for environmental protection have presumably been applied in the design, construction, and operation of factories, but compliance has been erratic.

In 1978 the EPO, with the powerful backing of the State Planning and State Economic Commissions, censured 167 industrial enterprises throughout the country and ordered them to take "proper measures" to control pollution by 1982. The order warned that if pollution was not reduced sufficiently during this period, the factories would be closed down and their managers held responsible. Even more significant, however, was the authorisation of funds and equipment to some of the enterprises to assist in waste management. This appears to be the first substantial financial commitment by the central government to pollution control in individual enterprises.

Because of a government policy shift away from large capital and energy-intensive projects, construction at the Baoshan Steel Works, 10 km north of Shanghai, was halted in February 1981. Expected to have been China's largest and most expensive industrial project, officials cited air pollution, the destruction of nearby wetlands and estuary, and land subsidence at the construction site, as reasons for abandoning the $14 billion undertaking.

could reduce waste loads and transform them more efficiently into "treasures".

However, high-level attempts to co-ordinate China's environmental policies and research efforts to devise regulatory approaches commensurate with the needs of a developing economy became evident only in the 1970s. By then air and water pollution had become serious, and concern that environmental mismanagement was polluting and degrading soil and water resources and thereby endangering agricultural production was growing. Because environmental threats to agricultural stability and productivity have always been a strong inducement for remedial measure, the scientific and technological establishment was formally asked to contribute to a national programme of environmental protection and reconstruction.

The result was a national conference on environmental protection, personally endorsed by Chairman Mao, held in Beijing in 1973. The delegates considered the results of a national survey that revealed the extent of air and water pollution in industrialised areas, the threat to the natural environment due to improper agronomic practices, the neglect and de-emphasis of environmental factors in factory location and construction, the ignoring of environmental considerations in order to satisfy production goals, and the inadequate technical capability for managing disposal and recovery of solid, liquid, and gaseous wastes. The recommendations of this conference, published as a State Council directive, formed the basis of China's national environmental protection programme.

Top priority among the administrative recommendations was given to the establishment of an organisation under the State Council to co-ordinate and implement the national programme. Similar lower-level bodies were recommended for provinces, autonomous regions, and provincial-level municipalities (Beijing, Shanghai, and Tianjin), although their functional responsibilities were left vague. The national-level Environmental Protection Office (EPO) was formed in 1974 under the State Council with a small staff. Its relatively low status as a co-ordinating and planning body was reflected in its designation as an "office" rather than as a more prestigious "commission" or "special agency".

Environmental administration

To pursue its co-ordinating and planning missions, the EPO has a science and technology division to supervise research, monitoring, and assessment in research institutions and a planning division to devise long-range environmental protection plans and to monitor compliance with regulations. The 1973 State Council directive authorising the EPO made some reference to its standard-setting functions, but did not spell them out. Impending organisational changes should centralise monitoring and standard setting in the EPO. New divisions—water, air, nature protection, and foreign affairs—were added in 1979.

In its role as national co-ordinating agency, the EPO regularly brings together officials from various ministries to consider the potential environmental effects and risks of industrial and resource development projects under their jurisdictions and to oversee expenditures of funds for environmental protection. Since production has always had the highest priority, however, protection needs have suffered, and there are few incentives for industrial ministries to invest funds in pollution control.

The EPO also has little influence over environmental research and development in the ministries and limited authority to levy fines. Furthermore, the extent of its influence in setting research priorities in provinces and provincial-level municipalities is unclear.

Provincial-level organisation varies from region to region. There is

A back alley near Ximen Road in central Shanghai, where 19th century architecture marks the area as originally part of the French Concession. The absence of litter here bears witness to the success of China's efforts in developing urban and rural communities that support large populations while adequately maintaining a healthful, sanitary environment co-ordinated scientific and technical research relating to either the monitoring or the control of air pollution. Areas of interest in the late 1970s included instrumentation and procedures for determining trace toxicants, laser scanning to measure particulate concentration, analysis of the flue gases from steel smelting electric arc furnaces, gravimetric analysis, and chemical member filter measurement. On the whole, however, the Chinese appear to be relying (quite sensibly) on air pollution technology available in the West.

Many scientific accounts of materials recovery research and environmental improvement emphasise the economic and health rewards of co-operative efforts by scientists, technicians, and workers to conserve and re-use industrial raw materials and to control pollution. In support of this, traditional techniques for composting organic and recycling inorganic materials have been improved. Since 1949, however, in the larger setting of environmental protection, this aspect of environmental sanitation (along with industrial hygiene) most commonly falls under public health councils and not under environmental science institutions.

Integrated management

Most of China's environmental research is done in conjunction with specific, economically important projects. Two excellent examples of integrated environmental research, assessment, and management are associated with Guanting Reservoir and Yaer Lake.

Guanting Reservoir, located in an arid region 100 kilometres north-west of Beijing, generates hydropower and supplies water and fish to the capital. Development of industries—metallurgical, mining, chemical, paper, tanning, and synthetic fibre—in the river valleys above the reservoir led to serious pollution. Under the combined authority of the reservoir administration and industrial environmental protection units, steps were taken to solve this problem.

One report described the organisation of a co-operative project, under way since 1972 and involving physical geographers, environmental chemists, and biologists, to describe and model the effects of pollutants on biological communities and ecosystems in the reservoir and to study the processes that govern links between pollutant sources and receptors. One aspect of this work was an analysis of the form, content, distribution, and chemical transformation of toxic heavy metals in reservoir sediments and their biogeochemical migration in the water-sediment aquatic organism system. Overall research and management achievements in the Guanting Reservoir area provide evidence of successful integration of agricultural and industrial production and environmental protection.

Integrated pollution control in a major fowl-breeding, aquaculture, and aquatic products area, Yaer Lake in Hubei province, began in 1976 under a plan drawn up at China's leading centre for research on fresh-water pollution, the Institute of Hydrobiology (also referred to as the Institute of Aquabiology) in Wuhan. Here, the problem was to restore a majority inland fishery that had been severely polluted since the late 1950s by effluents from pesticide and chemical plants built along its shores.

Engineering work involved installation of a network of pipes to drain polluted lake waters into four oxidation ponds that were formed by damming off a 200-hectare area of the lake. Treatment was then carried out through bacterial degradation and removal by algae. The Institute of Hydrobiology carried out wide-ranging experiments on the use of plant materials for removal of toxic chemicals from industrial effluents and the breakdown of chlorinated hydrocarbon pesticides from agricultural runoff. It also illustrated the complementarity of pollution control and economic productivity by harvesting *Phomidium ambiguum*, a blue-green alga used to remove ammonia nitrogen from acrylonitrile wastewater, for use as a fertiliser.

Future prospects

The Chinese government's reaffirmation of the importance of environmental protection in 1978-1979 and the publication of new environmental science journals and environmental protection laws are hopeful signs that environmental science will receive greater support, in keeping with the national effort to improve science and technology. However, analysis of scientific and policy documents leads to less sanguine conclusions for several reasons.

Chinese environmental research is only indirectly responsive to abatement goals and regulatory objectives. Because of the organisational structure and priority-setting mechanism of research units and government bodies, scientific and technical work are unlikely to serve national environmental protection needs in the immediate future. There obviously will be local exceptions and some research areas, such as environmental chemistry, environmental geology, and aquatic biology, could make significant contributions to the development of industry-specific control technologies and in environmental chemical analysis.

However, China is just beginning to think about environmental standards and regulations. Evidence of bureaucratic lethargy and mismanagement in implementing existing research and enforcement programmes abounds. It is also questionable whether China's central government planners' wish to include environmental factors in development planning decisions at high management levels.

The problem derives partially from funding priorities. Beginning in 1976 China has committed itself to billions of dollars worth of plant and technology purchases from foreign suppliers. These capital purchases will hasten the growth of the iron and steel industry, mining, telecommunications, oil production, energy development, and transportation. Although pollution control is of great concern to Chinese authorities, expenditures on indigenous research and development and on direct imports of control devices are likely to be far lower than needed. There is little reason to expect that this will change under the current policy for readjusting and restructuring the economy.

The direction followed by China in modifying its domestic and international environmental policies in line with its modernisation drive will be closely watched by the global community. Despite its domestic environmental problems, in bilateral relations and in its style of participation in international organisations, China has done much to enhance its national image. By sharing its experience in disease control, recycling, energy conservation, marginal land management, and small-scale water use, China has gained the admiration of many developing countries and of foreign advocates of conservation and soft technologies. Because of its size, population and physical diversity, China's emerging environmental policies will have major effect on growing international efforts to find a viable basis for environmental co-operation in the interest of human survival.

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How much do you know about METALLURGY?

HMMM...
ALLOY DOSN'T HOLD PROF.
M.

What is the difference between cast iron and steel? And what do you know about your stainless steel kitchenware? Here are a few such questions about metals. Answers overleaf.

1. The word "metal" has its origins in
A. Latin.
B. Greek.
C. Spanish.

2. Ever heard of the term "metalloid"? What do you think is a metalloid?
A. A term used to describe inferior metals.
B. A metal that does not form compounds.
C. An element having the physical properties of a metal, and behaving chemically both as a metal and as a non-metal.

3. Metals are crystalline materials. A crystal is an array of atoms in a repeating pattern. However, even in the best of conditions these crystals will be seen to have "point", "line", and "plane" defects. Annealed metals are those which are heat-treated and cooled so as to minimise the number of defects to achieve near perfection in the crystal structure. What do you think would be the usual concentration of defects in a "near perfect" crystal?
A. 10 per sq cm.
B. 10^{6} per sq cm.
C. 10^{12} per sq cm.

4. Although metals are normally crystalline in nature, under special conditions, some *alloys* can be obtained in "glassy" state. This is done by
A. beating the metal till all crystalline grains are completely broken.
B. rapid solidification of liquid metal.
C. extremely slow cooling of the liquid metal which has similar structure as that of glasses.

5. Stainless steel utensils are identified by their being non-magnetic. Which are the other important alloying elements present in utensil-grade stainless steel?
A. Magnesium and nitrogen.
B. Nickel and nitrogen.
C. Nickel and chromium.

6. Aluminium is a chemically reactive and soft material. However, its uses can be greatly diversified by a surface treatment. Which of the following surface treatments is usually given to make it corrosion-resistant?
A. Anodising.
B. Nitriding.
C. Sand blasting.

7. Old clocks, especially the grandfather clocks of the past, used to run slow in summer and fast in winter. This had to be corrected by adjusting the length of the pendulum. In 1896, Dr. Charles E. Guillaume invented an alloy which has almost zero coefficient of linear expansion with respect to its surrounding temperature (meaning, it hardly expands if heated). This alloy is called
A. invar.
B. inconel.
C. incoloy.

8. Natural uranium is a metallic element containing three isotopes (meaning, the atoms of uranium, although having the same atomic number have three different atomic weights). Which of the following isotope is responsible for giving uranium a place as fuel for nuclear power reactors?
A. U-238
B. U-235
C. U-234

9. As the carbon content in iron is changed, the strength of the iron changes. What is the difference between "cast iron" and "steel"?
A. They have the same carbon content, but different microstructures
B. Cast iron has a higher carbon content than steel.
C. Cast iron has a lower carbon content than steel.

10. The figure shows various everyday articles. Can you name them in increasing order of their carbon content?

11. Cranes with large electromagnets are used in iron and steel plants for transporting scrap material. However these are not used for transporting hot bars or ingots because
A. of the danger of accidents.
B. iron becomes non-magnetic when red hot.
C. the expensive electromagnets could get damaged when in contact with hot ingots.

12. Given below are some interesting terms from metallurgy. You will notice that most of them have other meanings in everyday life (you would not like being called a "creep", for instance), but in metallurgy these have special connotations.

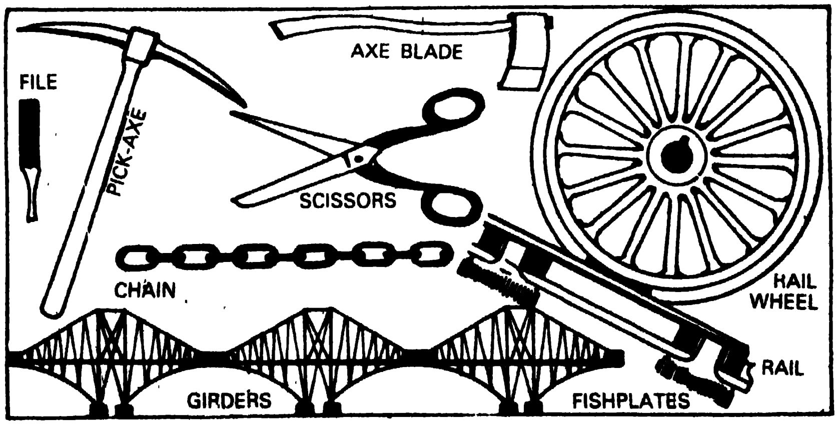
A. "Mild Steels" are
1. steels which react mildly with mineral acids.
2. low-carbon steels without alloying elements.
3. steels containing manganese, iodine, lithium and dysprosium as alloying elements.

B "Creep" denotes
1. metals that fails in an awkward situation
2. liquid metal flowing into the crevices of a solid body.
3. plastic flow under constant stress.

C "Fatigue" means
1. failure of material under external load
2. failure of material under repeated stressing.
3. failure due to high temperature and humidity.

D "Aging" describes the
1. time provided to relieve stresses.
2. time required for cooling hot metal.
3. formation of wrinkles on a metallic surface.

E High speed steels are
1. steels which can be cast quickly.
2. steels used in supersonic planes.
3. steels which maintain their cutting edges, even when the tool becomes hot.



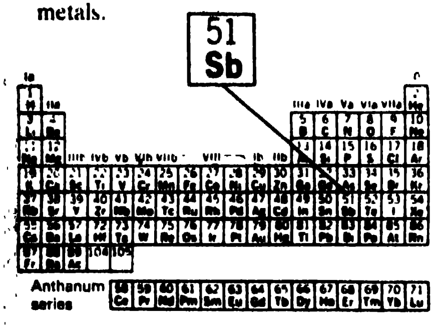
TROUBLE'S WITH THE CONTAINER PROF. TRY THOSE NEW REINFORCED PLASTIC ONES

The Answers

1.—B: Metallon meant "a mine" in Greek. The word must have got into the English language, like many modern English words, through French. In Old French, it was *metallum*.

16th century metallurgist's assay laboratory

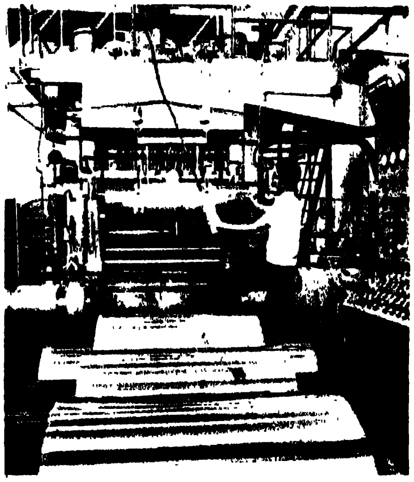
2.—C: Arsenic and antimony are good examples of metalloids. Both these are hard, crystalline solids metallic in appearance, but capable of reactions usually seen with metals *and* non-metals.



Position of antimony in periodic table. Arsenic (As) and bismuth (Bi) are also in the same group

3.—B: Some point defects and line defects are shown in the figure. Plane defects are like those marked g.b. and twin planes, on the two sides of which atoms are arranged as mirror images of each other (right).

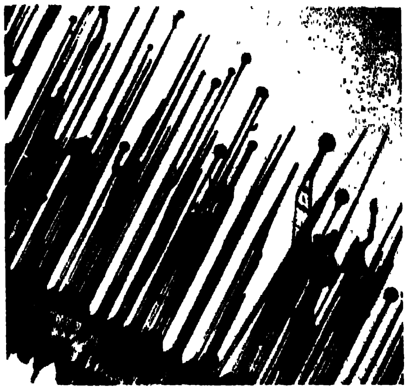
4.—B: Certain alloys, like aluminium alloys and nickel-based alloys, when cooled at extremely fast rates (of about 10^6 degrees centigrade per second) from their molten states can be prevented from crystallising. These have glassy structures, and often, very attractive properties like better corrosion resistance and high ductility.



Fresh aluminium sheets in a factory

5.—C: In utensil grade stainless steel, chromium (18 per cent) and nickel (8 per cent) are used for stabilising the "austenite" phase, which is non-magnetic in spite of 74 per cent iron in it. In the austenite phase, it can easily be formed into shapes.

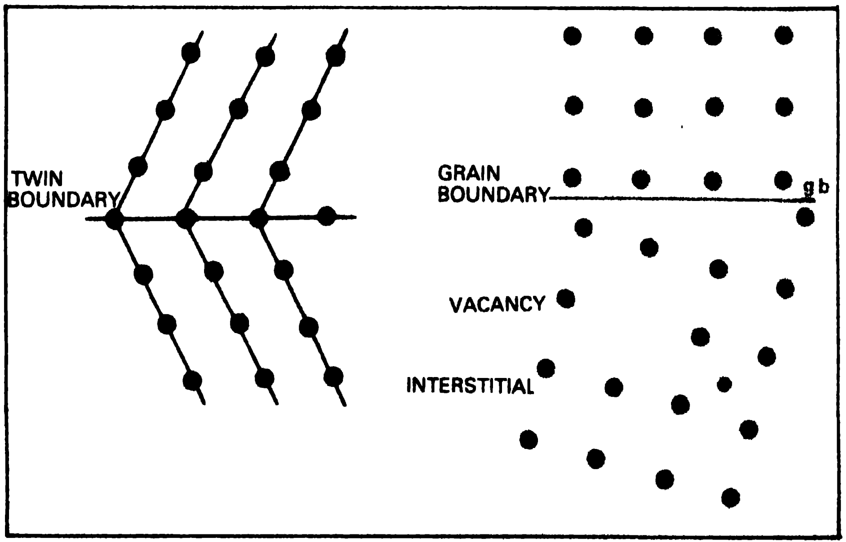
6.—A: By electrochemically treating aluminium and using the object as an anode, an oxide layer can be generated on the surface. Whether the layer will be bright, dense, or porous, will depend on the electrochemical parameters. Porous layers can be treated with dyes to give enduring colours, since the oxide layer is hard and transparent.



Near-perfect crystals of aluminium oxide grown in the laboratory. These can take enormous stress

7.—A: Invar is an alloy of iron and nickel (36 per cent). Magnetic materials change their lengths both because of temperature and magnetisation. When they demagnetise, on heating above a certain temperature, they shrink. By choosing a suitable composition, not only can the temperature at which demagnetisation occurs be selected, but also, thermal expansion and contraction due to demagnetisation can be balanced to neutralise each other.

8.—B: Atoms having the same number of protons (and hence electrons) but different atomic weights are the isotopes of the same element. The process of splitting a nucleus into two smaller



Common defects found in a crystal

nuclei is formed as fission; the mass lost during this reaction is converted into energy, as per the equation $E=mc^2$, where E denotes energy, m the mass, and c the velocity of light. The only naturally occurring substance fissionable by slow neutrons is uranium-235. You can imagine how much energy a small amount of uranium can release, considering that the factor c^2 comes in the equation.

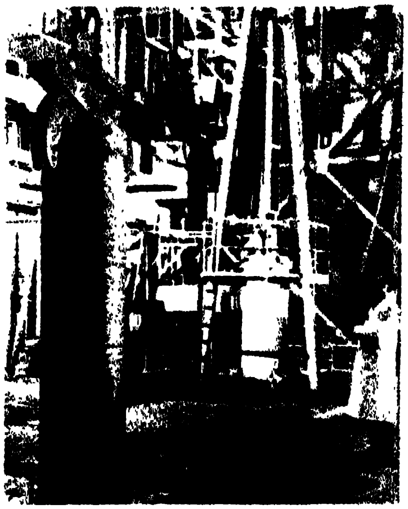
Uranium minerals copper uranite and autunite. Uranium minerals are typically green or yellow in colour

9.—B: With up to 1.7 per cent carbon, the alloy can be heated to bring it into a single phase (austenite), which can easily be shaped. This is the notional limit below which iron-carbon alloys are called steels. If the percentage of carbon is higher, iron carbide (Fe_3C), which is hard and brittle, remains present at all temperatures up to melting point. Compositions with more than 1.7 per cent carbon are generally called cast irons.

10. The usual percentage of carbon used in the objects are as follows:

Chain	0.05
Girders	0.25
Railwheel	0.40
Rails	0.55
Pickaxe	0.80
Axe blade	1.00
File	1.30
Scissors	1.40
Fishplate	3.50

11.—B: Since iron and common steels become non-magnetic above around 800°C (the Curie point), magnetic methods of transporting cannot be used for ingots above this temperature.



Ingot of remelted metal. Note the clamp used to shift it

13.—A-2; B-3; C-2; D-1; E-3.

This quiz was prepared by N. C. SONI and ASHOK MOHAN of the Metallurgy Division, Bhabha Atomic Research Centre, Bombay.

ATTENTION

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"Lord, how my head aches!
What a head have I!
It beats as it would fall in twenty pieces."

Romeo and Juliet, II, 5

WHY DO YOU GE HEADACH

Sunil K. Pandya

Many factors lead to pains in the head. A headache could stem from a defect in your eyes, the tensions of everyday life, noise, or blood pressure, to name but a few common causes.

HOW common a plaint and how widespread, affecting all sections of society. As the English proverb goes, when the head aches, all the body's the worse for it. Work and entertainment, food and fancy are alike forsaken. Holding the aching head, the sufferer takes to bed only to find that Morpheus too deserts him. The result: abject misery.

Despite their frequency and generality, headaches are poorly understood. Most of us are hard put to realising that granny's headache stems from a cause different from that plaguing her teen-aged grand daughter. It also seems strange to many why one member of the family is given nose drops for his headache while another undergoes extraction of an impacted molar and a third is advised yoga. When headaches follow a repetitious pattern and are accompanied by other symptoms, anxiety is compounded and panic may follow receipt of news that a neighbour with similar problems has just undergone surgery for removal of a brain tumour. Are there different types of headaches? How does one recognise variants? Can some headaches signify serious illness? What could one do to cure a persistent headache?

Psychogenic headache

Sushila, despite umpteen varieties of tablets that guaranteed relief from the most severe headache, found it difficult to concentrate on her work. As she started on her household duties, she would experience that incapacitating ache in the head, however determined she would be. Her mother-in-law's suggestions only made matters worse. She was forced to seek refuge in her bedroom day after day, leaving work undone. Mixtures, tablets, capsules and even injections prescribed by the family doctor proved ineffective.

Gently, but surely, the doctor got her to voice her problems. Listening long and patiently, he traced the headaches to their roots. The husband was surprised when, instead of prescribing yet some more drugs, the doctor referred her—and him as well—to a nearby fertility clinic.

The doctor had learnt of the taunts the young housewife faced from her mother-in-law and others at her inability to produce an heir. Her frustrations were projected into her consciousness as severe headaches. It was discovered that the husband needed treatment to ensure impregnation. Once this was attended to, the mother-in-law saw progressive evidence that satisfied her desire to become a grandmother. As the taunts died, so did the headache. Not all the stories have such happy endings.

Some headaches stem from problems within the mind. Such headaches are usually diffuse, vague and flit from one part of the head to another, finally settling over the top of the head. They worsen when frustrations are aggravated or when there is deliberate provocation. They diminish when the person is at ease. Such headaches do *not* usually respond to analgesics and persist till the cause is eliminated. Headaches from some anxiety states may respond only to skilled psychiatric therapy.

Tension and anxiety

Mohammed's wife was deeply concerned. Ever since her husband had been put in charge of the company's sales programme, he was prone to episodic bouts of headache. He would spend half the night poring over papers, preparing various sales strategies. Even so, he would be in good cheer at breakfast and leave for work with a smile. In the evening, however, especially after a meeting where his strategies had been hotly debated, he would return exhausted, complaining of pain in the back of his head. Time after time, she was forced to break commitments made to friends or relatives as he was in no shape to stir out. When she tried to help by rubbing balm over the pained areas, she found the muscles at the back of his head and upper neck tense, rigid and painful.

Such tension headaches are all too common in the hurly-burly of modern existence, especially among those constantly under pressure to better themselves. The fierce competition in most spheres and the knowledge that there's always someone waiting to show his one-upmanship over you to the boss results in anxiety. The muscles of the head and neck are put under constant tension. In protest, they send impulses, interpreted by the brain as headache.

As with psychogenic headache, the obvious solution is to eliminate the provocation, but this is easier said than done. It is not always possible to change corporate attitudes, the personality of one's boss or the nature of one's mother-in-law. It is of considerable help for the patient to learn, consciously, the art of relaxation, especially of the muscles of the head and neck. Some claim wonders for transcendental meditation while the proponents of yoga put forth their claims. The lover of music will claim that all that is needed is a Mozart symphony played in an appropriate setting. Whatever the means, the goal is the same—relaxation, ten-

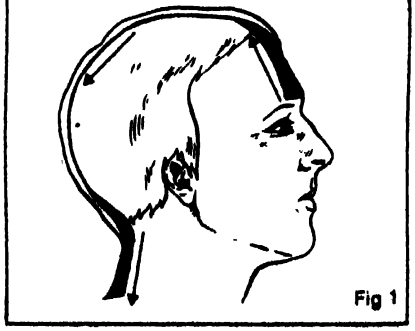


Fig 1

THOSE
ES?

sion-shedding, peace. Drugs provide transient relief only and are not to be recommended.

Ophthalmic problems

Little Rohit often comes home from school complaining of headache. When questioned in detail, he confesses that he cannot see clearly what his teacher writes on the blackboard, especially since the teacher moved him to the last row in the classroom. His adolescent brother complains of headaches, especially after he has spent three hours in a movie theatre. Their grandpa, on the other hand, complains of headache after a session with the weekly newsmagazine. He must read every word in that fine print but at the end he holds his head with both hands. The eye specialist finds a common basis for their symptoms—eye strain. Due to errors in refraction in each of them, the visual image did not fall accurately on the retina. In order to sharpen the blurred image, reflex and barely conscious efforts were needed to bring the image in sharp focus. The muscles in and around the eyes, subjected to unnatural strain, produced nerve impulses decoded by the brain as signals of pain in the forehead. Similar aches are experienced by individuals who have recently acquired a squint. In an attempt at fusing the two images resulting from the squint, a consciously created imbalance of the finely attuned eye muscles is brought about with consequent strain. In most instances, corrective lenses—contact lenses or spectacles—have put an end to the complaint. Persistent squint may require corrective surgery.

Inflammatory diseases in and around the eye produce throbbing pain in the forehead and around and behind the eyes. Increase in intraocular pressure (glaucoma) can produce severe headache and associated vomiting.

Ear, nose and throat ailments

The heavy head accompanying a nasty "cold in the head" may be the precursor to episodes of headache localised to one or both sides of the forehead and face. The nasal catarrh is associated with swelling of the mucous membrane lining the paranasal sinuses and its ducts. An excessive quantity of mucus is therefore poured into the sinuses at exactly the same time that their ducts are blocked. The pent up mucus produces the heavy head and subsequent ache. In some cases, the mucus is secondarily infected leading to sinusitis. The pain is now throbbing, constant and often unbearable. The accompanying fever makes matters worse.

While nasal decongestant drops and steam inhalations may be all that's needed for the heavy head accompanying a stuffed nose, sinusitis demands treatment by a specialist. The pus has to be drained and appropriate antibiotics used to control the infection. In some instances it may be necessary to carry out an operation to evacuate pus and diseased mucous membrane.

A related form of headache—histamine headache—follows inhalation of fumes to which the person is

Fig 1: Rear neck muscles pull on scalp causing muscle contraction headaches. Fig 2: Anxiety headache as a tight band around the neck. Fig 3: Sinusitis—pain over the sinus. Fig 4: Trigeminal neuralgia—stabbing pain usually over the lower part of the face

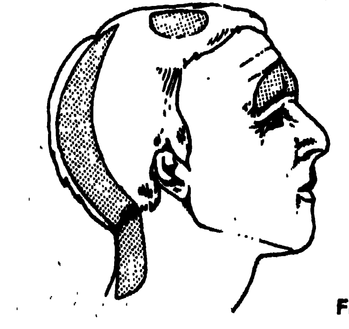


Fig.2

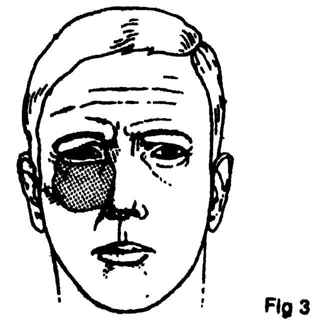


Fig 3

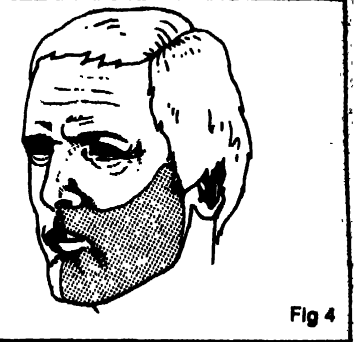


Fig 4

allergic. Some chemicals, strong attars, the musty and dank odours emanating from an inadequately ventilated cinema hall are some examples of provocative agents. Even after one has got rid of the cause, the mucus outpouring may continue for several hours. It may be necessary to resort to anti-histaminic drugs to obtain effective relief from pain.

Infection in the inner ear causes severe pain in the temple and the back of the head. Such pain is of ominous significance. Unattended, such disease can spread to destroy the inner ear and produce deafness. Worse, infection can spread from the ear into the skull to produce meningitis and or a brain abscess, at times with a fatal outcome. The need for careful, complete treatment of any infection of the middle and inner ears is thus obvious. It is also evident that as tonsillitis and recurrent sore throat may lead to infection of the middle ear (through the Eustachian tube connecting the throat and ear), these too must be carefully treated and not neglected. (Pain from infection in the external ear can be quite severe but is easily cured. It is usually due to a furuncle or "boil". As regards serious complications, this external infection is almost completely innocuous and hence need cause no anxiety.)

Most people also suffer headaches when they are told that their carious teeth need removal and that they should therefore see a dentist. The sensations induced by the very thought of visiting a dentist is a favourite theme with cartoonists. But this is not the headache we are concerned with. Rather, it is the headache caused by diseased teeth that concerns us. A decayed, infected tooth hurts but the pain is localised to the infected tooth and its neighbourhood. There is an exception and that is when the infection involves the third molar. The pain from this tooth is referred to the head and is experienced as a headache. The third molar can produce such headache even without any decay or infection involving it. In some individuals, instead of sprouting upright, the third molar is malaligned, ending up in a horizontal position with its crown abutting the second molar and its roots pressing against the jawbone, irritating adjacent sensitive nerves. Such headaches may cause confusion in diagnosis and the patient may go from doctor to doctor till someone blessed with both knowledge and experience asks whether the headache is worse when chewing hard food or biting upon hard objects. On obtaining an affirmative response he requests the patient to open his mouth, and spots the problem. The exact diagnosis is made after studying an x-ray film of the affected tooth. The cure is simple—removal of the troublesome tooth.

"Ice-cream headaches" are a variant of this form. The intense cooling that follows the eating of ice-cream produces pain signals in the nerves serving the carious tooth. These signals are referred to the head. In some individuals, cooling the roof of the mouth also serves to provoke headaches, the pain impulses in this case originating from the palate.

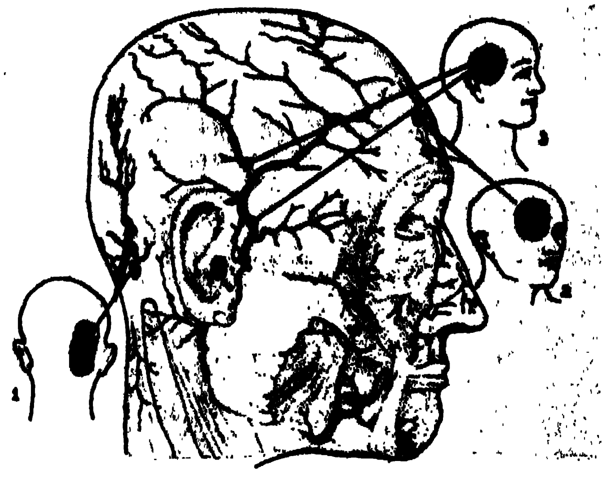
Blood pressure

The heart pumps blood throughout the body under pressure. When the normal, mild fluctuations in blood pressure are exceeded, either too much or too little blood flows into the scalp, the coverings of the brain and the brain itself. When the blood pressure is unnaturally low, there is a relative insufficiency. This is experienced as a dull headache and giddiness. A few complain of faints. When the blood pressure is abnormally high, blood pounds through the scalp and brain, distending the arteries. The patient complains of throbbing, pounding headaches. He may also have associated visual symptoms. In the state termed "malignant hypertension", some arteries in the eye and the brain are stretched beyond their tensile limits, and consequently, they burst. Blood pours into the eye and the brain. The brain swells. If a fairly large artery within the brain ruptures, the bleeding is extensive. The splitting headaches worsen rapidly and the patient soon loses consciousness. A fatal end is not uncommon. Lesser clots produce severe headaches, cloudy consciousness and various kinds of paralysis. Bleeding within the eyes may leave the individual blind.

It is thus obvious that the blood pressure should be maintained within the normal range. Fortunately for most of us, nature does this without any effort on our part. As long as we remain symptom-free, we need spend neither time nor thought on the issue. Some of us, for varying reasons, are prone to fluctuating blood pressure. Once attention is called to this state by symptoms, it is important to stabilise pressure. Low blood pressure—a rare state—must be treated by attending to its cause. The commoner high blood pressure state is often without detectable cause. In such instances, where dietary measures by themselves are insufficient in bringing about a stable state, drugs may have to be used but under the supervision of a physician only. Patients with high blood pressure are advised to avoid situations that cause psychological stress. This advice is easier to offer than to implement. Yoga has been shown to have some effect in lowering blood pressure. Remember that the commonest cause of headaches in those with high blood pressure is anxiety over their blood pressure.

Hunger and hangovers

A professor of medicine at a college—one who was sincere, hardworking and intelligent—developed episodic headaches. He would be so disabled that he had to leave the outpatients' section or the lecture hall to return to his office and lay his head on the table. Those around him noted an excessive irritability before and during these attacks. His family bore the brunt of his unnatural tantrums. It was many weeks before it was realised that his headaches occurred only when a meal had been



Arteries of the scalp. Dots indicate the points of stimulation causing pain. 1. The occipital arteries. 2. the supra orbital and frontal arteries, and 3. the superficial temporal artery

Of aches, pains and thresholds

ODDLY, while an obnoxious individual may prove a "headache" to one of those around him, he may be termed a "pain in the neck" by another. What is the difference between ache and pain?

Chambers' Twentieth Century Dictionary defines an ache as a continued pain. Harold Wolff, on the other hand, describes deep pain as having "an aching quality", suggesting the qualities of dullness and poor definition as being applicable to an ache. Pain is derived from the Latin *paena*—a penalty. The suffering felt while doing something or consequent to an action was thus pain. The pains of childbirth are an example. While pain is indefinite as to the degree or quality, sharp pain is termed pang, severe and lasting pain agony, and overwhelming pain anguish. Pain and anguish are applied indiscriminately to what is physical and mental. (*Crabb's English Synonyms*.)

Doctors classify pain into superficial and deep varieties. Pain from noxious stimulation of the skin has a pricking, cutting, burning or itching quality and is sharply localised. It evokes prompt corrective response. Pain from deeper structures and organs is diffuse, difficult to localise and associated with nausea, changes in blood pressure and, occasionally, syncope. It leads the afflicted individual to withdrawal, inactivity and rest.

The threshold for pain varies. The frenzied soldier battling at the front may scarcely notice the bullet shattering his arm while the frightened child quails at the very sight of a hypodermic needle. The same painful stimulus may be felt differently by the same individual under differing circumstances or by different individuals at the same time. A multitude of factors thus governs the severity of pain: cultural background, the assumed significance of pain, the amount of distraction, the presence of mental depression, past experience of pain, and so on. As Rene Leriche pointed out, physical pain is not a simple affair of an impulse travelling at a fixed rate along a nerve but rather the resultant of a conflict between a stimulus and the whole individual.

Antiphanes's statement that all pain is one malady with many names now appears dated. Charles Illingworth sums present concepts: "Every sentient being knows what is meant by pain but the true significance of pain eludes the most sapient. For philosophers, pain is a problem of metaphysics, and exercise for stoics; for mystics it is an ecstasy, for the religious, a travail meekly to be borne, for clinicians a symptom to be understood and an ill to be relieved."

S. K. P.

RAISE YOUR HAND WHEN IT HURTS!
..AAH...
BANG
TELL ME, DOC HOW DO I DO IT ?!
M/ON

delayed or skipped. Once this correlation was established, he soon uncovered the cause of his headaches. During one such episode of pain, blood was drawn and tested for sugar. The level of sugar was very low. Within minutes of drinking a concentrated sugar solution, the blood sugar level rose. Simultaneously, the headache and irritability disappeared. He now carries sugar cubes with him all the time and whenever he feels the headache coming on, pops one into his mouth to abort the attack.

Headache produced by hunger is not as well recognised as it should be. It is commonly seen in persons who, as a recent advertisement has it, "have everything but time" and are forced to skip snacks and meals. Such individuals are usually slim, hyperdynamic and perfectionist. While some of them recognise their disability and devise simple corrective measures, a surprising number end up in clinics after umpteen unrelated tests have been carried out.

Even though Austin O'Malley defined a drunkard as being like a whiskey bottle—"all neck and belly and no head"—on the morning after, the guzzler feels nothing but his head. There he lies, literally holding his head, fearful of the slightest sound or jerk because of the shock waves it sends screaming through his head. The associated nausea makes him spurn any drug or nostrum. It will take several hours for him to be able to hold his head erect once again and even contemplate a smile.

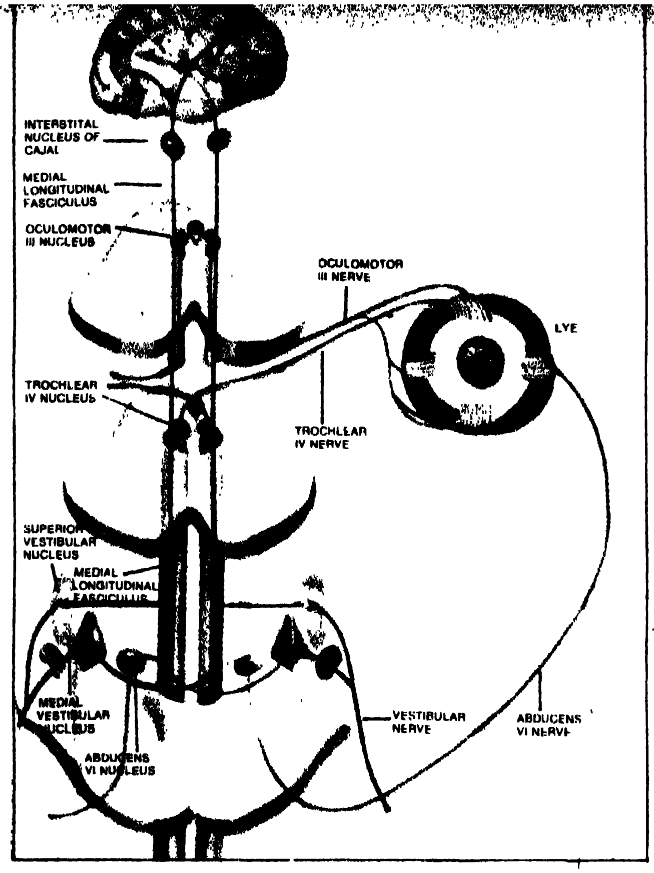
Alcoholic drinks contain ethyl alcohol, water and congeners—ethyl acetate, iso-amyl alcohol, various sugars, minerals and some vitamins. The concentrations of these congeners range from 3 g per 100 litres in vodka to 285 g per 100 litres in bourbon. These congeners (so called because they lend the characteristic colour and flavour that make the different beverages appealing) and metabolites from the drink (such as acetaldehyde) cause the hangover. The headache is considerably worsened by previous intake of mono-amine oxidase inhibitors as the tyramine in the drink reacts with these drugs to raise the blood pressure.

The obvious cure for such headaches is, of course, totally unacceptable to those most plagued by them. Advice on restricting the quantity quaffed too falls on deaf ears. For those not blessed (as Bertram Wooster was) with a genius named Jeeves who shimmies in bearing a life-saver on a plate the morning after, the only acceptable advice may be that counselling against drinking on an empty stomach. Consuming large quantities of water after the binge also helps by preventing dehydration of vital tissues in the head and, at the same time, diluting the concentrations of the congeners. The hangover may thus be mitigated if not totally prevented.

Chinese food and hot-dogs

The relative exoticity of Chinese food has attracted innumerable afficionados, and the recent emergence of Chinese food vendors on the streets will enslave many more. It may come as an unpleasant surprise for some of this ilk to learn of the problems brought on by such food. Half an hour after starting a Chinese meal, susceptible individuals suffer pain in the forehead and temples. This is associated with a sensation of tightness over the face and chest. Studies (especially in the North American continent) show that the culprit is the monosodium glutamate added to Chinese food to improve taste. Three grams of this chemical is enough to cause serious problems in those susceptible. A helpful hint: the

Doctors use their knowledge of the control mechanisms for eye movements to localise the sites of intra-cranial diseases, and judge the extent to which deeper structures in the brain are damaged. Such information is of vital significance in the managements of patients with severe headaches caused by intra-cranial haemorrhage and tumours of various kinds


INTERSTITIAL NUCLEUS OF CAJAL
MEDIAL LONGITUDINAL FASCICULUS
OCULOMOTOR III NUCLEUS
OCULOMOTOR III NERVE
EYE
TROCHLEAR IV NUCLEUS
TROCHLEAR IV NERVE
SUPERIOR VESTIBULAR NUCLEUS
MEDIAL LONGITUDINAL FASCICULUS
MEDIAL VESTIBULAR NUCLEUS
ABDUCENS VI NUCLEUS
VESTIBULAR NERVE
ABDUCENS VI NERVE

pain is less likely if soup is avoided. Glutamate in the soup is rapidly absorbed into the blood stream. Glutamate eaten with solid food is absorbed much more slowly and thus does not reach troublesome concentrations in the blood stream.

Another food additive responsible for headaches is nitrite, used to give an uniform red colour to meats. Hot-dog and salami fanciers thus may be treated to a large dose of nitrites with consequent widening of their scalp and brain arteries and a migraine-like headache.

Migraine

"I wake up in the morning feeling happy. The sky seems more blue, in fact, all colours appear more intense. I know that this means that later that day or perhaps the next, I will get a migraine attack. The pain gradually comes on over one temple, usually the right, and spreads over the whole of that side of the head. At the same time, but sometimes before the headache begins, part of my vision blurs, bright stars may appear and move over the field of vision. The headache becomes worse and throbbing, I start feeling sick. If I vomit, this seems to make the headache better. With the headache, light hurts my eyes so I have to go to bed after drawing the curtains. The whole attack lasts about eight hours and leaves me tired and shaken."

Clifford Rose and Gawel quote this typical case history in the opening chapter of their book on migraine. The word migraine itself is a corruption of the Greek term for one-sided headache (*hemi-crania*). Most sufferers talk of a warning signal (termed "aura" by doctors) noted minutes, hours or even a day before the attack. The patient soon learns to recognise his aura. The headache itself is usually in the form of a crescendo and may be accompanied by visual symptoms—either those as described above, or the presence of a zig-zagging bright-edged line across the field of vision, or fragmentation of the object seen, or a distortion in perspective similar to that when we look through the wrong end of a telescope. Some patients suffer migrainous neuralgia where there is a sensation of a red hot needle being stuck into the eye. The eye is red and its movements painful. Migrainous neuralgia comes on in cycles repeating every 8, 12 or 24 hours for one or more weeks. Rarer forms of migraine are associated with transient weakness of one half of the face, the eyes or one side of the body. In an unusual form, the pain is experienced not in the head but in the abdomen. Diagnosis can be difficult unless history of migraine in other members of the family is forthcoming.

The mechanism of migraine is gradually becoming clear. The arteries of the scalp and brain are principally involved. These arteries initially narrow abruptly as their muscular coats go into spasm. This phenomenon, restricted to one side of the head, lasts 10 to 30 minutes. The visual aura is attributed to such spasm in the artery supplying the occipital lobe of the cerebrum. Later the same arteries undergo abnormal widening resulting in a flood into previously starved areas of the scalp and brain. It is the excessive blood pouring into sensitive arteries that is responsible for the pain.

The biochemical basis for the initial narrowing and later widening is being studied. Intermittent release of 5 hydroxy-tryptamine (serotonin) into the circulation is postulated on the basis of increased excretion of its end-product, 5-hydroxy-indole acetic

The sites of pain

AT TIMES, pain originating at one site is localised by the sufferer at a different and apparently unrelated site. An example is pain felt by the patient just above the eyes when it originates from the heart. This unusual feature is explained on the basis of observations made by Sir Henry Head, an eminent neurologist and thinker. He found that in an organ which is innervated by the tenth cranial or vagus nerve, the area of referred pain is within the distribution of the fifth cranial or trigeminal nerve, as this latter distribution represents the somatic sensory distribution corresponding to the vagus. Head observed that in general, the higher the site of origin of pain in the trunk, the farther forward is the correlated area in the head. Thus, the upper chest is associated with areas over the [illegible] forehead, the middle third of the chest with the top of the head and the temples and the lower chest with the back of the head.

Some neurophysiologists explain headaches which are produced by bright lights, noises and powerful odours on a somewhat similar basis. Since the spe- [illegible] acid, in the urine during and soon after an attack. Serotonin constricts blood vessels. The role of those prostaglandins (SCIENCE TODAY, October 1978) that narrow blood vessels (and also produce clumping of platelets with subsequent release of more serotonin) is being investigated. The part played by tyramine is also under study. There is little doubt that in several instances, susceptibility to migraine is inherited. It is also well recognised that several factors can trigger off such attacks in susceptible individuals. Most doctors put stress at the head of the long list of triggering factors that include chocolates (rich in beta phenylethylamine), cheese and red wine (rich in tyramine) and fried foods, sexual intercourse, alcohol and smoking. In time, sufferers learn what they are susceptible to and avoid them. Migraine may also be associated with menstruation or come on as a woman approaches menopause (leading to speculation on the role of hormones in its causation). The contraceptive pill has been known to spark off severe headaches. While some of these may be migrainous, others have been proven to be due to clotting of blood in cerebral veins—a serious condition.

Some patients remain free from migraine without recourse to drugs. Biofeedback, currently in fashion, has been pressed into use. The patient is made aware of distension in the temporal artery, spasm in the muscles of the neck and increase in the temperature over the head and is taught to concentrate on reducing these. Meditation (transcendental or otherwise), yoga and acupuncture have their proponents. Many drugs have been used. Preparations from ergot (a mould growing on rye) have proved very effective. Used at the onset of the migrainous aura, these preparations can abort the attack. Tricyclic compounds (amitryptaline), L-tryptophan, clonazepam, lithium and a host of other drugs are being tried out. Some clinicians prefer to stick to standard analgesics and tranquillisers.

Trigeminal and other neuralgias

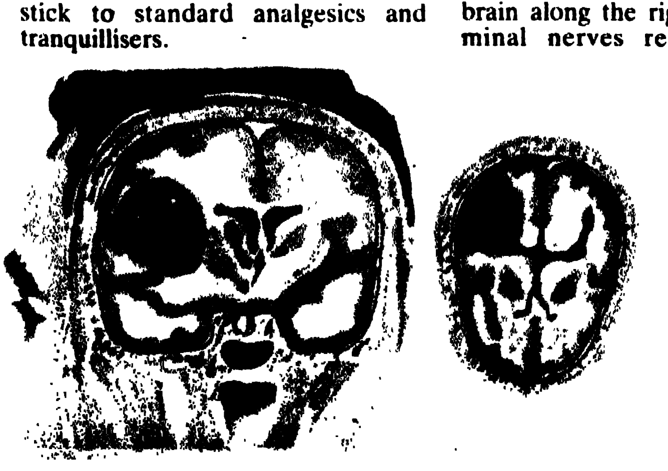
Mehroo, a middle-aged housewife, was helped into the clinic by her husband. She walked with a slight stoop, protecting the left half of her face with her left hand. She sat hesitantly on the edge of the chair and stared at the doctor, reluctant to speak. When questioned, she gestured with the right hand, pointing to the left side of her face. She looked miserable. The left cheek was raw from friction and somewhat dirty. From time to time she stiffened and clutched at her face. A couple of minutes later, still rigid, she started rubbing the left cheek, gently at first and with greater force. Her husband narrated her tale of woe. For the past week she was plagued by episodic, sharp pain ("like electric currents"), shooting down the left side of her face. The pain lasted a minute or so and then eased leaving behind a dull ache. The sharp pain recurred every 10 to 15 minutes. Any attempts at opening the mouth or talking sparked off the pain. Eating was almost impossible and she swallowed fluids with great difficulty. As the days passed, the intensity and frequency of pain had worsened.

Sensations from the right and left halves of the face are conveyed to the brain along the right and left trigeminal nerves respectively. Each nerve has three divisions subserving the upper, middle and lower thirds of the face respectively. When the nerve or any of its divisions is inflamed and irritated (as by virus infection), neuralgic pain (as in the instance above) follows. The pain is severe, sharp and recurrent. It is usually restricted to the distribution of the affected division but may, over months, spread to involve the other divisions as well. It does not cross the midline. Irritation or stimulation of key areas on the face ("trigger zones") sets off acute attacks. Movements of the jaw—during speech or chewing—also spark off severe attacks. The characteristic story and absence of any neurological abnormality on examination make the diagnosis easy. Treatment, in most cases, consists of carbamazepine tablets. In refractory cases, it may be necessary to paralyse the pain fibres in the respective divisions using radiofrequency current. It is unusual, these days, to have to resort to the old operation of cutting the painful nerve.

Other nerves around the face and mouth may also be similarly involved to produce other types of neuralgias. Fortunately most such neuralgias also respond to drug therapy. Where the neuralgia is secondary to irritation of the nerve by an infected tooth, abnormal blood vessel or tumour, appropriate surgery will be necessary.

Tumours and other lesions

Six-year-old Anita had always been an ebullient child. Of late, though, she was less prone to venture out, jump, dance and run around with joy. When asked what was wrong, she complained of the pain in her head. Her mother consoled her with thoughts of a wedding in the family and prescribed an aspirin. When this did not help, a larger dose was given. Despite the tablets, she remained miserable and was reluctant to go to school. Firmly, mother insisted that she not give way to these "trifling aches" and sent her off. On returning that afternoon, Anita's cheeks bore tear stains. She had suffered two nasty bouts of headache in school and had even vomited once. As the pain persisted over subsequent days and vomiting became more frequent, a *vaid* was consulted. Ground herbs in milk were prescribed. She brought these up. The pain worsened and was now constant. Anita found it difficult to retain her food. She was also prone to fall while attempting to walk. Her mother interpreted these as being due to weakness. Meanwhile Anita complained of seeing double—two images of every object she



Cut sections of the brain showing haemorrhage into the cerebral hemisphere. Headache may follow increase in pressure within the cranium, or irritation of structures at the base of the brain by blood

Harold Wolff's epochal contributions

UP TO the 1930s, most recorded descriptions of headache were based on oral evidence and little was understood of the precise mechanisms involved in the production of the different types of headache. Consequently, diverse and, at times, contrary opinions were held and treatment was often empiric, aimed principally at relieving discomfort.

The observations inspired by one man changed all this. Harold Wolff, Titzell Professor of Medical Neurology at Cornell University Medical College, USA, devoted himself to unravelling the mysteries of headaches. In addition to painstaking and accurate notes made at the patient's bedside, he carried out elaborate neurological tests and detailed physical examinations. Psychiatric studies were also carried out. Observations were made during surgery under local anaesthesia (where the patient remained fully conscious) on the teeth, nose, paranasal sinuses, ears and the brain and its coverings. The effects of stimulation of various exposed tissues were carefully noted. Over the years, he was able to map out the exact location of pain felt by the patient when different parts of the nose, throat, teeth, eyes, paranasal sinuses, and ears were stimulated or irritated. Similarly, he was able to delineate the exact sites where pain was felt when arteries on the scalp were tugged, crushed or otherwise irritated, when arteries supplying the brain itself were stimulated, when the different coverings of the brain were stimulated at different sites and so on. His observations during brain surgery on conscious patients produced the most dramatic results. In some patients, he was able to mimic the development of a clot or tumour in the brain by inserting a balloon into different parts of the brain and then inflating the balloon. The type and extent of pain that followed were carefully recorded. Of course, he also noted the type and location of pain complained of by patients who were known to have brain tumours. The pain was then correlated with the exact location, size and extent of the tumour as noted during its removal.

These studies laid the foundations for our present understanding of pain-sensitive structures in and around the brain and the significance of different types of pain in the head in relation to their causes. From the maps drawn by Wolff and his colleagues, it is possible for the modern clinician to localise and define the disease process producing the pain.

Wolff showed conclusively that much of the brain itself was totally insensitive to pain and could be handled and cut into without the patient experiencing any discomfort. Most headaches, he showed, emanated from fatigued, overworked muscles in the upper neck, stretched coverings of the brain (in particular, the dura mater), inflamed leptomeninges (pia-arachnoid) and blood vessels of the scalp, dura and the base of the brain. He also highlighted the role of distortion of the pain-sensitive structures in the dura, falx and tentorium produced by focal increase in intracranial pressure in causing headache. His studies culminated in the publication of *Headache and Other Head Pain*, the 700-page classic.

Wolff also exposed the complicated nature of the subject. The effects of personality, environment, aspirations of the individual on the physical and chemical effects of the disease process are so complex and varied that only a part of the various facets of the headache syndrome can be evaluated with any semblance of accuracy.

S. K. P.

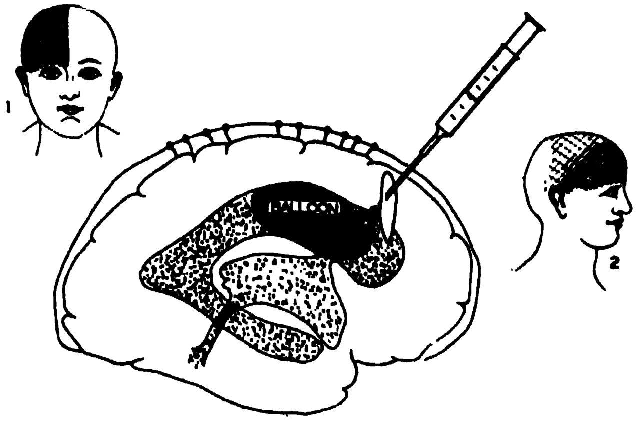


Diagram illustrating Wolff's balloon experiment on live humans undergoing brain surgery. Area of pain resulting from distension and collapse of the balloon in one lateral ventricle is shown as shaded areas in 1 and 2

looked at. By the end of the second month, everything seemed blurred to her and gradually her vision blacked out. She was bedridden, unable to stand without falling.

It was at this stage that the civil surgeon was consulted. As he looked into her eyes through the ophthalmoscope, he saw marked swelling of the optic nerves and deduced high pressure within the head. He confirmed his findings on X-rays of the skull which showed the bones forming the skull vault being pushed apart. He also found evidence of disease in the hind brain. Suspecting a tumour in the cerebellum, he advised immediate transfer of the little girl to Bombay, where she was promptly admitted in a public hospital and eventually the tumour was removed.

Headaches produced by brain tumours and other "space-occupying" or "expanding" lesions (such as abscesses, cysts, chronic granulomas, etc) are usually progressively severe and persistent. They occur with increasing frequency and are worse when the patient coughs or strains. They are usually accompanied by nausea and later vomiting. Disturbances in eyesight follow—double vision, blurred vision, episodic blackouts and finally blindness. (Even after tumour removal, the patient does not recover vision if blindness has set in before surgery.) In most instances, some form of dysfunction of the brain is also noted—epilepsy, abnormal gait, weakness of the face or limbs, sensory abnormalities, involuntary movements, etc. Delay in diagnosis spells prolonged suffering for the patient. Brain tissue damaged by the enlarging tumour will not regenerate and the patient may thus be left with permanent handicaps. Untreated, the tumour causes eventual compression of vital parts of the deep, centrally situated brain stem resulting in coma and death.

Hemorrhagic strokes

Take the case of Firoz. He aspired to a career in modelling. He, therefore, took great care in grooming himself. On the advice of a friend, he decided upon heavyweight-lifting in order to make a he-man out of himself. Though he was advised to start off with relatively light weights, he decided to take a short-cut and so approached the barbell that had just been laid down by a veteran. As he took hold of it and strained to lift it to his knees, his head felt as if something exploded inside. The barbell dropped from his hands and he stood dazed. Before his colleagues could rush to help, he had sagged to the floor, clutching his head in pain. In a minute or so he had retched and vomited. He continued to moan with pain and kept holding on to his head as though he feared its coming apart. As his friends tried to make him sit, they noted his neck being rigid as a board. Any attempt at moving the head or neck brought forth screams of pain. It was obvious that he was very ill. Later, tests in hospital showed that he had bled from an arterio-venous malformation within the brain. The abnormal mass of blood vessels was surgically excised and he showed progressive recovery.

While a person may bleed into his brain following a severe rise in blood pressure, another, with normal blood pressure, but harbouring abnormally fragile blood vessels in the brain may also suffer thus. In some, abnormal tangles of fragile vessels form during the development of the brain and this tangle (or arterio-venous malformation) may give way resulting in bleeding. In others, one or more arteries may have developmental weak spots which, over time, thin and blow out into little balloons. The balloon may burst at its thinnest part with consequent bleeding. If the blood pours predominantly into the water containing spaces around the brain (subarachnoid spaces), the patient suffers severe, splitting headaches that later give way to an almost unbearable ache spreading from the head into the neck and back. He may remain fully conscious, but reel in agony. Should he bleed directly into the brain substance, loss of consciousness and paralysis may rapidly follow the severe headache. Since the bleeding is consequent to a developmental abnormality in the blood vessels, it is difficult to predict in a hitherto asymptomatic individual. Unaccustomed physical stress is likely to provoke bleeding in such persons. It is possible to exclude the abnormal vessels from the circulation by delicate and highly specialised surgery.

Serious brain diseases

The investigation and treatment of severe, persistent headaches, especially when associated with evidence of brain dysfunction are best carried out in well-equipped centres. Such centres are to be found in most large teaching hospitals in capital cities and in the larger private centres. The patient may need hospitalisation. After a detailed clinical examination, x-rays of the head and neck are obtained and studied. The electrical activity of the brain may be recorded (electroencephalogram) and analysed. In some cities, it is possible to do computerised axial tomographic scanning. The films obtained after such a scan show the skull and brain in sections. We can now actually look into the living brain and study its various components without carrying out any operation or subjecting the patient to any hazard.

What to do when your head aches

There are thus headaches and headaches. Fortunately, most of them stem from transient, self-limiting conditions and are easily cured. Simple measures and an analgesic or two may be all that is required. In a few instances, however, headache may point to a serious underlying disease needing careful and, at times, specialised treatment. It is often difficult for a layman to distinguish the sheep from the wolf in sheep's clothing.

"And did the doctor say one aspirin nine times a day, or nine aspirins once a day, Vibhishan ol' boy?"

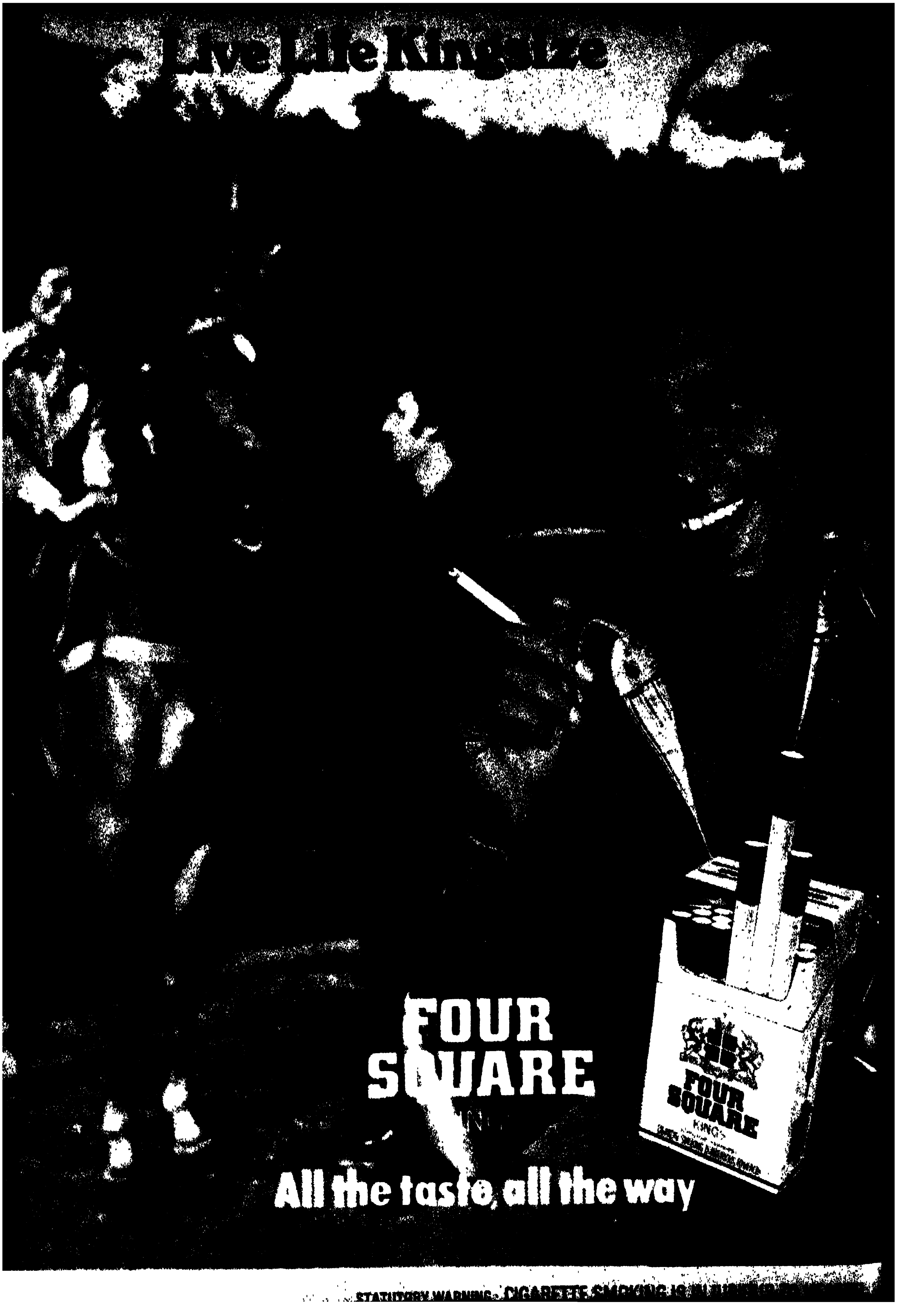
Most headaches, then, will resolve spontaneously or with the help of simple measures and a tablet or two to relieve the initial ache. Any headache that persists more than a few days, recurs, increases progressively and relentlessly in intensity or reaches a state of constancy should prompt a medical consultation. When the pain is associated with nausea, vomiting, visual disturbance or abnormal drowsiness, a sense of urgency is imparted to the situation. Likewise, any sudden sharp, splitting headache accompanied by prostration, fits or paralysis needs urgent attention. If in doubt about the significance of a particular headache, it is better to err on the safe side and consult your family doctor. It is dangerous to persevere with domestic or folk remedies or experiment with different pills and potions in persistent headache with associated symptoms of brain dysfunction.

In most instances, your family doctor will be able to take care of your problem and you need go no further. Having started therapy as advised by him, it is important that you remain under his observation. Progress and, even more important, lack of it, should be reported to him. If he is dissatisfied with your progress, he may request some tests—x-rays, blood and urine examinations, etc. Where necessary, he may seek counsel from a specialist in cardiovascular diseases (as in cases of intractable high blood pressure), an endocrinologist (where there is unexplained, periodic lowering in blood sugar concentration), a psychiatrist (where a disorder of the mind is suspected) or a neurologist and neurosurgeon (where disease in and around the brain is likely).

As with medicine in general, precise diagnosis must precede therapy. Once the diagnosis is established, the doctor can start appropriate measures to effect a cure. These include intensive drug therapy, the insertion of a valved tube to drain accumulated cerebrospinal fluid, elimination of fragile, abnormal blood vessels from the circulation and the removal of expanding lesions in and around the brain.

Yet, once in a way, doctors do encounter patients who perplex them. There is the story of the patient who went to his umpteenth doctor complaining of persistent headache. He never drank. He never smoked. He never over-ate, and no, he never bothered with women. The doctor drew a blank on examination and on all the tests he ordered. The gray-haired doctor looked at the patient pensively and gently opined: "Well, perhaps your halo is too tight!"

Dr. Pandya is Professor of Neurosurgery at the King Edward Memorial Hospital and Seth G. S. Medical College, Parel, Bombay.


Live Life Kingsize
FOUR SQUARE
FOUR SQUARE
KINGS
All the taste, all the way
STATUTORY WARNING: CIGARETTE SMOKING IS

APPLE seeks its slot in space

U. R. Rao and R. M. Vasagam

With the APPLE mission, space technology in India has taken a jump. How was the spacecraft manoeuvred ?

KOUROU in French Guyana, hardly 30 km away from Devil's Island, which was once a notorious penal colony, today serves as a picnic spot for visitors and scientists working at the vast technological complex of the Guyana Space Centre. At 9.33 am local time (18 hours, 03 minutes IST) on19 June, Ariane lifted itself into space from Kourou, carrying two satellites—METEOSAT (meteorological satellite) and APPLE (Ariane Passenger Payload Experiment of the Indian Space Research Organisation). Sixteen minutes later METEOSAT separated, followed by the separation of APPLE spacecraft. APPLE, was now on its own, in a highly eccentric transfer orbit with its perigee at 201 km and apogee at 36,206 km, circling the Earth with a period of 10 hours and 40 minutes. And the drama which led to the eventual placement of APPLE at its destined position begins unfolding with a mathematical precision. How was the spacecraft manoeuvred into position? What were the problems it faced?

The project APPLE was born with the following objectives in mind: (i) build and launch an experimental three-axis body-stabilised (that is, stabilised in all the three axes and devoid of roll, pitch and yaw motions) geostationary communication satellite with its own apogee propulsion system and attitude and orbit control system for conducting communication experiments in the C-band, (ii) obtain experience in injection into a geostationary orbit from a nominal synchronous transfer orbit and carry out on-orbit management, including attitude control and station-keeping, and (iii) conduct experiments in communication technology and its applications in domestic communication, radio networking, data relay, remote area communication, etc.

Post-launch manoeuvre

Since the launchers leave the satellites in a highly elliptical transfer orbit, all communication satellites require a number of complicated manoeuvres to put them in the final orbital position. The first step in this process is to raise the perigee from 200 km to almost 35,000 km by firing the apogee boost motor, deploy the solar panels (see box on p. 66), achieve three-axis stabilisation and finally move the satellite to its nominal position in the geosynchronous orbit (synchronous with the Earth's rotation). This, in turn, should enable precise pointing of the communication antenna with an accuracy of 0.1° towards a fixed location on the Earth, before operating the transponders for their intended applications.

The first step after the injection of APPLE into the transfer orbit involved the testing of the reception of telemetry signals from the satellite (downlink) and the status of the command uplink. The telemetry downlink provided the vital first information report on the satellite health as APPLE became visible over SHAR within half an hour of the launch. The power output from the stowed solar panels with a maximum array current of 4.84 amperes, performance of the chemical battery as well as the power regulation and control electronics were found to be normal. The thermal control system functioning was also found to be satisfactory with almost all the systems located inside the satellite experiencing temperatures within the safe limits of 0° to 40° C. The first test commands were issued successfully within 10 minutes of the visibility of the satellite over the radio horizon of SHAR. Subsequently, the spacecraft was continuously commanded from Indian and European Space Agency ground stations

The second step was to determine the line-of-sight distance to the satellite. This was done by ranging the satellite using the onboard VHF transponder with the ground-based uplink carrier modulated by a number of tones. This method exploits the well-known Doppler principle involving frequency shifts resulting from the relative motion of the satellite with respect to the ground station. Using sophisticated softwares that took into account a host of effects perturbing APPLE in its motion round the Earth, including gravitational asymmetry arising from the shape of the Earth and the atmospheric drag, the position of the satellite as a function of time was precisely calculated, with a few metres accuracy over distances of the order of 40,000 km.

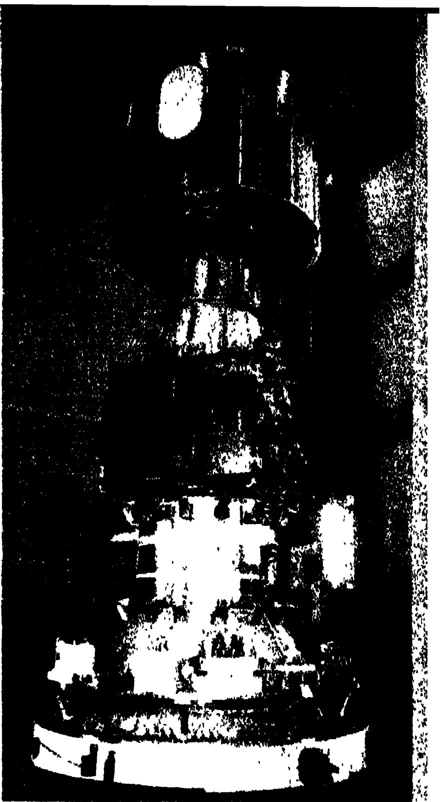


Fig 1. Fully assembled APPLE along with METEOSAT and CAT mated to the last stage of the Ariane launcher

The third important step was the determination of the orientation of APPLE in space with the help of the onboard infrared sensor, which detects the crossing of the Earth's horizon, and Sun sensors. Using an elaborate computer software that suitably modelled the data from these sensors and through a series of complex coordinate transformations, the attitude of the satellite and its spin rate were calculated to better than a fraction of a degree. The satellite was found to be spinning at 10.2 revolutions per minute. Four independent approaches, geometrical, least squares, Kalman filter and dynamic method were employed to confirm the results.

The fourth step was to orient the spin axis towards the desired spin vector for firing the apogee boost motor (ABM). Even with Ariane injecting APPLE with its spin axis within 5° of the nominal direction, three sets of fine attitude trimmings had to be carried out to finally set the satellite within 0.1° of the desired direction and keep it ready to carry out the first major manoeuvre—circularising and chang-

[illegible] of the improved version of [illegible] stage motor of the [illegible] hydrazine thrusters [illegible] necessary thrust and [illegible] for attitude control, [illegible] orbit control manoeuvres. A large number of Sun sensors and Earth sensors are used for determining the attitude of the spacecraft; they also provide the inputs for the control of the satellite. Attitude is stabilised with the help of the momentum wheel.

Two solar panels, held in stowed condition during launch, are deployed in orbit and made to continuously track the Sun to obtain maximum power, with the help of the solar array drive assembly. Power during eclipse periods is provided by the nickel cadmium battery. In the transfer orbit phase and in the initial phase of APPLE operation, spacecraft ranging and telemetry was at 137.5 MHz (very high frequency or VHF) with the command operation being carried out at 149.5 MHz. Provision for ranging via VHF uplink and the C-band beacon downlink was also incorporated.

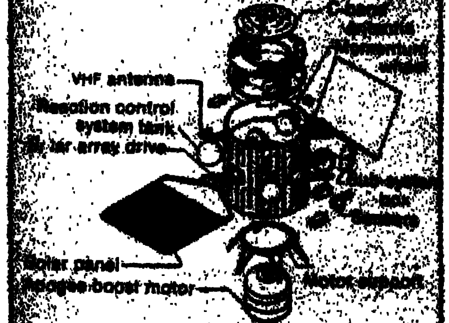


Fig 2. Disassembled view of APPLE

The payload consisted of two C-band communication transponders, in a redundant mode, connected to a 900-mm-diameter parabolic reflector made of aluminium honeycomb with carbon fibre "reinforced plastic" face sheets. The C-band communication payload, working with the uplink at 6 GHz and downlink at 4 GHz, was configured to be compatible with the ground segment established and checked out earlier during [illegible] (Satellite Telecommunication Experimental Project) time frame. Specially fabricated multilayer blanket insulation and optical solar reflectors cover the spacecraft to keep the thermal environment within the spacecraft between [illegible] and 40°C. Thus APPLE incorporates practically all the features and technologies used in the current generation geostationary communication satellites such as [illegible], RCA Satcom and INSAT-I.

ing the plane of its orbit through apogee motor firing.

APPLE was spun up to 63 rpm to impart better gyroscopic stability by generating small torques by firing the hydrazine thrusters. The precise time and orientation of the spacecraft as it passes through the sixth apogee was calculated using ranging data. Then the ABM was fired as the spacecraft crossed the sixth apogee point at 0413 hours IST on 22 June which imparted an incremental velocity of 1,440 metres per second to the satellite. The operation is tricky considering that a precise velocity increment has to be imparted by igniting the apogee motor around 15 seconds of its passing the apogee point after ensuring that the satellite spin axis is maintained within 0.1° of the desired direction. Computations of the orbit parameters using extensive ranging data gathered over ten hours indicated that the satellite was raised almost to the geosynchronous orbit with an apogee of 35,900 km and perigee of 30,500 km.

The second major manoeuvre was to deploy the solar panels. For this, the spin rate of APPLE was reduced to 0.5 rpm with appropriate thruster firing and the pyrocartridges were fired by command to enable the release of the stowed solar panels through the solar panel deployment mechanism. Subsequent analysis of the data indicated that only one panel was deployed and the other was stuck. Efforts to dislodge this panel by artificially increasing the centrifugal forces through spinning up the satellite up to 25 rpm failed.

Having checked and ensured that the 140 watts power obtained from even one solar panel was adequate to fulfil the APPLE mission (which requires only 120 watts), the third major operation of three-axis stabilisation was taken up. The first part of this manoeuvre involved acquiring the Sun through the Sun sensors. After some initial troubles, arising primarily from the blocked view of the Sun sensor which could not be deployed, the Sun was acquired and the deployed solar panel was enabled to continuously track the Sun to provide maximum power output by actuating the solar array drive assembly.

Holding the spacecraft with its solar panel facing the Sun, APPLE was oriented towards the Earth by sensing the infrared radiation emitted by a thin layer of carbon dioxide in the Earth's atmosphere down below with the help of onboard scanning and static horizon sensors. With the spacecraft stabilised in three axes by firing hydrazine thrusters in this position, the momentum wheel was actuated. As the momentum wheel slowly picked up speed and finally stabilised at its design value of 3,500 rpm, the stabilisation of APPLE spacecraft was transferred to the wheel from the hydrazine thrusters on 24 June. Subsequent observations indicated that the pitch axis control with the momentum wheel was satisfactory with the pitch error being held within 0.05°

In the phase following the three-axis stabilisation and pitch control with momentum wheel, a series of roll/yaw corrections were carried out manually through thruster firings that brought the roll error to within 0.1°. Roll was further controlled by switching on the magnetic torquer. APPLE is the first spacecraft to employ a magnetic torquer for roll control in the closed-loop mode.

Now followed a series of orbit-raising manoeuvres to correct the residual errors after ABM firing and put the satellite in a precise geosynchronous 24-hour orbit. The hydrazine thrusters were fired for a total of 200 minutes during the period 24-26 June; this resulted in an apogee of 36,950 km, a perigee of 34,700 km and a period of 23.96 hours. Further, the satellite was imparted a net westward drift velocity of 0.42° per day with the satellite at 124° East. On 30 June, hydrazine thrusters were fired again for 8.5 minutes that increased the drift rate to 1.75° per day to speed up the movement of APPLE towards its final destination of 102° East.

As the APPLE spacecraft approached 102° East longitude, hydrazine thrusters were fired again on 12 and 13 July for a total of 11 minutes to slow down the spacecraft and reduce its westward drift from 1.7° per day to 0.2° per day. The final correction was carried out on 16 July to place APPLE in a 24-hour orbit over 102° East longitude and begin its mission. The spacecraft in this position will be maintained within 0.1° of 102° East.

The time when APPLE was slowly drifting towards its final position was utilised to check out the performance of all subsystems, including communication transponder payloads on the spacecraft. In addition to verifying the gain, distortion characteristics and other technical parameters, both TV patterns and live signals were transmitted via APPLE from the Ahmedabad Earth Station.

The anxious moments

In a complex mission like APPLE, there are bound to be unforeseen eventualities that could tax the brain of even the most resourceful scientist. To overcome such situations, contingency and work-around plans have to be made after understanding the nature of the problems through analysis and simulations. We shall discuss a few such events and the way they were tackled.

The sun sensor paradox: Soon after the injection of APPLE, the measurement of the spin rate of the satellite with the help of the twin-slit Sun sensor ran into difficulty since the output from the sensor appeared abnormal. Switching over to the redundant sensor by a ground command did not improve the situation. A two-pronged attack to solve this problem was mounted. The prototype of APPLE was used to simulate the on-orbit situation which revealed that at low spin rates, the combined response of the sensor and its front-end electronics was indeed sluggish. This meant that a direct measurement of this important parameter was out of the question. Meanwhile, spacecraft experts stationed at SHAR ploughed through the maze of computer data from the sensors to find alternative ways of extracting this information. And within an hour, they came up with the ingenious suggestion that a particular combination of data from the Sun sensor and the infrared horizon sensor, that involve the transit time signal from these sensors as their field of view successively swept across the solar disc, could be used to derive the spin rate parameter. The computer programme developed for accepting the normal type of data from the Sun sensor, was quickly modified taking into account the anomalous effects and the spin rate was derived to be 10.5 rpm and that too to an accuracy better than an eighth of a millisecond, far in excess of what was needed for the mission.

The ABM puzzle: The crucial sixth apogee at which the ABM had to be fired was fast approaching. Preparatory work was initiated almost two-and-a-half hours before this critical one-shot operation. The sequence of operations included checking and verifying the reliability of the uplink, configuring the onboard telemetry system to enable near-continuous monitoring of the critical parameters relevant to the ABM operation, monitoring the temperature distribution in the satellite, arming the ABM preparatory to its firing and finally issuing the critical command that ignited the motor. The suspenseful moments immediately following the firing of ABM were further accentuated by the sudden loss of the telemetry signals from the satellite for the next 32 seconds by all the ISRO and ESA ground stations. Even though in retrospect this loss of signal could be interpreted as the result of the intense flame attenuation during the burning of the propellants inside the motor, and as such a positive indication of the motor ignition, the immediate reaction at the mission control was one of extreme concern. As soon as the downlink was restored, data were searched to find the first evidence for the success of the ABM firing. The Sun sensor showed that there was no appreciable deviation in the orientation of the satellite. There was a small change in the spin rate and the motor temperature indicated a slight warm-up. But the crucial issue was how to quickly confirm the final performance of the ABM. Generation of the new orbit information through extensive ranging and orbit computation was likely to take not less than six hours.

In these anxious moments, a new idea was born. The infrared horizon sensor that measures the width of the Earth infrared emission layer could enable the computation of the satellite altitude, if its orientation in space is known a priori. It was quickly computed that the pulse width from the sensor should become zero at exactly 25 minutes from the time of ABM firing, if the orbit is geostationary. If the spacecraft continued to be in the elliptical transfer orbit, it should happen only after 50 minutes. But precisely at 25 minutes, it was confirmed through the pulse width indications that the performance of the apogee motor was normal and that APPLE was in the desired geostationary orbit! Hours later, precise orbit computations from the tracking data confirmed these preliminary results of the horizon sensor.

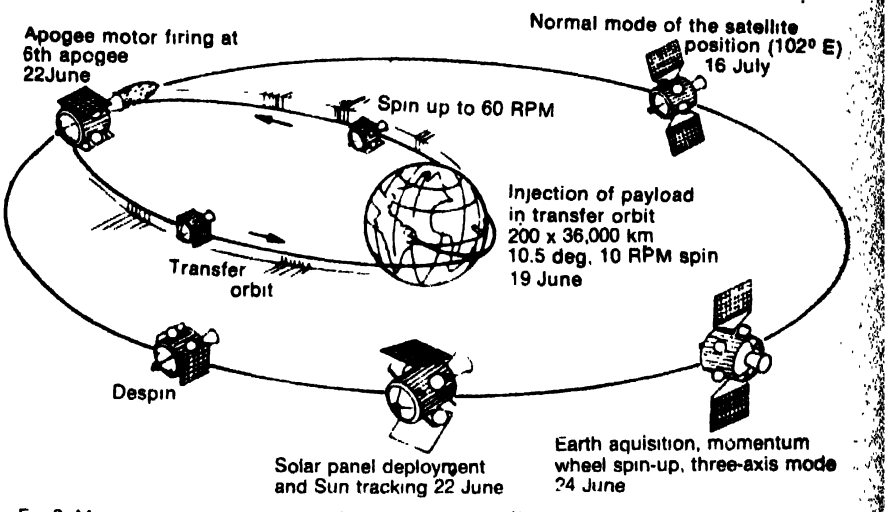


Fig 3. Major manoeuvres to place the APPLE spacecraft in the geosynchronous orbit over 102° East longitude

The solar panel that did not deploy: When the commands for deploying the solar panels from their stowed positions were issued, the first indications of the results were rather perplexing. While it was generally concluded that only one of the two panels had deployed, it was not clear whether the north panel had deployed or the south. Through a careful analysis of the sensor data, especially those from the 4π steradian Sun sensors (Sun sensors with an opening angle of four π degrees) mounted under the solar panels, it was concluded that only the south panel had deployed. This, in turn, posed a new set of challenges not foreseen in the mission operations plan.

The first concern was the question of attitude stability of the satellite due to unbalanced perturbation torques such as that arising from the solar radiation pressure. A quick calculation established that this aspect is not likely to be critical, even though there could be higher roll/yaw error build-up requiring more frequent corrections. Another source of problem was the shielding of the optical solar reflectors used for thermal control by the north-side stowed panel. Thermal simulation runs in the computer revealed that there could be thermal build-up resulting in increased temperatures at some of the subsystem locations. A plan, involving controlled power dissipation and load-shedding, was evolved to maintain the temperature within reasonable limits.

Three-axis stabilisation: With the problems posed by the shielded Sun sensors, an alternative way had to be found to acquire the Sun. After reviewing all the possibilities, it was decided to try this operation with the fine Sun sensor even though its field of view was limited. To ensure that the fine Sun sensor sees the Sun, the satellite spin axis was oriented at 90°

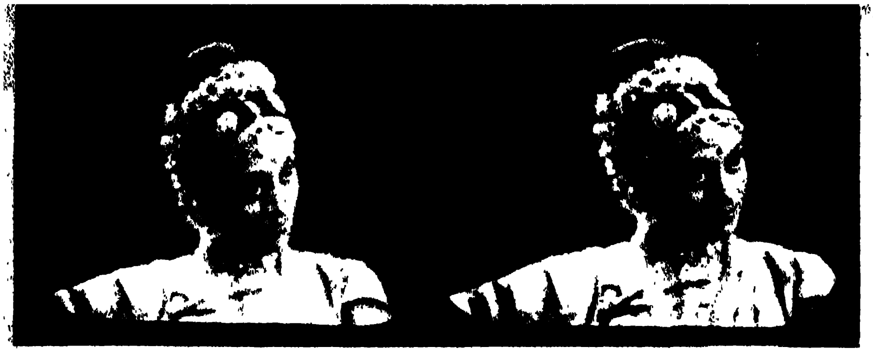


Fig 4. Live TV picture transmitted via APPLE. The received picture (RX, right) shows slight difference in the expression compared to the transmitted one (TX, left) because the received picture actually corresponds to the one transmitted 300 milliseconds earlier from the ground, the time-lag for TV signals to travel to and from the spacecraft

with respect to the direction of the Sun. As anxious minutes trickled by, waiting for the acquisition of the Sun along the roll axis, it was found that only the pitch error had reduced whereas the yaw error was building up. Analysis of this puzzling situation led to the conclusion that the sun-presence signal was available only for a short time because of the partially shielded Sun sensor, resulting in problems of quick response of the control system. To circumvent this difficulty, an ingenious idea of spinning the satellite in the reverse direction was suggested. This could increase the overall time available for Sun acquisition. This trick clicked and the roll channel was able to lock on the Sun direction perfectly.

Immediately following Sun acquisition, commands for Earth acquisition were given. From the altitude of the satellite, the Earth appears as a small disc of approximately 17.5° and for Earth acquisition this results in a short duration window of one hour. With the arrival of the Earth-presence signals, commands were issued to capture the Earth in the pitch loop. By the time the command was executed on 23 June, visibility was over for the day, and the operations had to be suspended. However, the pitch loop controller continued to search the Earth and in that process developed large pitch errors.

While restarting the Earth acquisition procedures again the next day, it was noticed that the satellite had developed an unexpectedly high spin rate of 24 rpm. Analysis of all the previous operations and their impact on the satellite dynamics led to the conclusion that during the previous day's unsuccessful Earth acquisition, the Earth sensor continued to give maximum signal which resulted in large disturbances in pitch direction. In course of time, the pitch got converted to yaw and since the yaw axis had the maximum moment of inertia, the spin got stabilised around the yaw axis.

Having solved the mystery of the anomalous high spin, preparations were again initiated for Earth acquisition after necessary despin and reverse spinning operations. The second attempt proved successful with the closing of the pitch and roll loops occurring within minutes of the Earth acquisition.

The satellite was thus stabilised with the roll and pitch signals from the scanning horizon sensor and the yaw error signal derived by onboard computation using the digital Sun sensor output. The thrusters in all directions were firing to correct the residual errors and finally the frequency of thruster firing reduced. The satellite became three-axis stabilised. A few minutes were left to allow the oscillations to die down.

APPLE initially carried 42.5 kg of hydrazine fuel for attitude, orbit and station-keeping manoeuvres, of which about 30 to 35 kg was earmarked for attitude and orbit manoeuvres. After placing APPLE in the geosynchronous orbit over 102° East, the fuel budget indicates that about 35 kg of fuel has been spent so far, leaving about 8 kg for station-keeping during its projected mission duration of one year.

The challenge

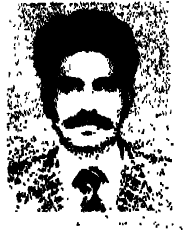
APPLE is a tangible evidence of a quantum jump in ISRO's technological capability to the level of building a three-axis stabilised geostationary communications satellite and establishing the necessary infrastructure to integrate, test, operate and utilise it. Only the USA, Europe, the USSR and Canada have demonstrated such capability.

The manyfold advantages of a communication satellite to a country like India in providing improved telecommunication services with minimum dependence on terrestrial links, practically maintenance-free TV distribution and radio networking systems and education of rural masses are now well established. While APPLE will make such applications feasible, other experiments such as educational TV , computer interconnection, remote area and emergency communication and teleconferencing will also be carried out using transportable two-way earth terminals and small communication terminals for receiving only. And despite only one C-band transponder being operated at a given time, APPLE will have the capability to provide an equivalent of one colour TV or 600 voice communication channels ("What APPLE means", SCIENCE TODAY, July 1981, P.63).

The era of satellite communication for India is just round the corner. INSAT, the first operational three-axis stabilised multipurpose communication satellite, is scheduled to become operational within the next year and provide communication, TV and meteorological services to the entire country. Two satellites, procured from the USA, are expected to provide these services for the next 7 to 10 years. The successful completion of the APPLE programme has now given greater confidence to build future operational communication satellites which will follow the INSATs.

Meanwhile, ISRO has already begun the design of a semi-operational Indian Remote Sensing Satellite (IRS), the first of which is expected to be ready for launch in 1985. IRS-1 is being designed to carry multispectral cameras to provide resources information on agriculture, forestry, hydrology, geology and land usage with a resolution of about 40 metres—a significant leap over what was achieved by Bhaskara. The design of IRS, which is a three-axis stabilised spacecraft, employs all the technological experience gained through Bhaskara and APPLE. APPLE and Bhaskara have thus enabled ISRO to move from an experimental stage to an operational era.

Prof. Rao is Director of the Indian Space Research Organisation Satellite Centre at Bangalore. The design and fabrication of Aryabhata, Bhaskara, Rohini and APPLE satellites were carried out under his overall guidance.



Mr. Vasagam heads the Control and Sensor Division of the ISRO Satellite Centre, Bangalore. He was also the Project Director for the APPLE Spacecraft Project.

FUN WITH MATHS

Peculiarities of 1089

THE four digit number 1089 has a number of interesting properties, among them are some which are unique to it among all four digit numbers.

Firstly, 1089 is a square number, the square of 33. It is not itself a palindromic number, that is, a number which remains the same when its digits are written in the reverse order, for example, the numbers 17371, 4001, etc. 1089 however can be written as the product of two palindromic numbers. Since it is the square of 33, a palindromic number, this property is obviously satisfied. But there is another way too, 1089=11×99.

It has another property which is also connected with palindromic numbers. The digital root of a particular number is obtained by summing its digits, and if necessary the digits of this resulting sum and so on, until we get a single digit number. So 1251 has the digital root 1+2+5+1 = 9. For 72381, we have 7+2+3+8+1 = 21, a two digit number. So we sum digits again, 2+1 = 3 to get the digital root. Now, 1089 can be expressed as the product of its digital root and a palindromic number. The digital root of 1089 is 3, and 1089= 363×3.

Now for its unique properties. 1089 is the only four digit number which is reversed when multiplied by 9. Thus,

1089×9=9801.

The next property of 1089, I will call "the same old number property". Take the number, reverse the order of its digits and add this number to the original number. Take the result and subtract from it the number formed by reversing the order of its digits. The number now has the "same old number property" when the final result is the original, same old number! 1089 is the only four digit number to have this property. Thus,

1089 + 9801 = 10890
10890 - 09801 = 1089.

There is a simple proof of why 1089 is the only four digit number possessing these properties. If you work it out you will also be able to say whether there are any numbers with five, six or seven digits which also satisfy these properties.

The last interesting property, not unique to 1089, is connected with prime numbers. There is only one way that 1089 can be expressed as the sum and the difference of two primes, one prime being common to both. Thus,

1089 = 1087 + 2.
1089 = 1091 − 2

Can you guess why?
(Answers next month)

D. V. RAMA KRISHNA

Mr. Rama Krishna studies at the Engineering College, Anantapur, Andhra Pradesh.

A

2	1	4
3	5	7
6	9	8

B

18	23	1	7	24
6	12	9	10	20
21	15	13	11	5
22	16	17	14	4
2	3	25	19	8

Magic squares with alternate subtraction

A VARIETY of interesting magic squares have been described by K. N. Malathi (SCIENCE TODAY, February 1981, p. 51) Below are two magic squares, 3 × 3 and 5 × 5, respectively, of an interesting variety. Take any row, column or main diagonal. Then, preserving the order of the numbers, add together the numbers in the odd numbered cells and subtract those in the even numbered cells and the result will be the same.

For example, in A, the first row gives 2+4−1=5, the second column gives 1+9−5=5 and the main diagonals give 2+8−5=5 and 4+6−5=5. For B, the second row gives (6 + 9 + 20) − (12 + 10) = 13, the fourth column gives (7 + 11 + 19) − (10 + 14) = 13.

Adding any number to all the cells in the square will not change the property, though it will change the constant result.

G. S. DHAMI

Mr. Dhami is studying at the P.G. College, Pithoragarh, Uttar Pradesh.

142857 explained

D. R KAPREKAR had described a very interesting property of the number 142857 in a previous issue (SCIENCE TODAY, May 1981, p. 55). Take any number formed by the cyclic arrangements of its digits and square it. Now cut the number into half and add together the two numbers which result If this sum has more than six digits, then add the leftmost digit to the rightmost one to make it a six digit number. The digits of this number will now be a cyclic arrangement of the digits 142857.

Dr. Pratipkumar Chaudhuri from Presidency College, Calcutta, and Mr. Aloke Majumdar from Nagpur have both sent in explanations of this behaviour of 142857. We give below an explanation based on the shorter and simpler one sent by Dr Chaudhuri.

The number 142857 and the numbers obtained by a cyclic rearrangement of its digits can all be expressed as multiples of 142857. Thus,

$$N_p = p \times 142857, \text{ where } p = 1, 2, 3, 4, 5, \text{ or } 6$$

But 142857 can itself be expressed in two ways, so that

$$N_p = p \times 999999/7 \text{ —— A}$$
$$N_p = p(7 \times 20408 + 1) \text{ —— B}$$

Multiplying the right hand sides of A and B will then give us the square of N_p so,

$$\begin{aligned}(N_p)^2 &= p \times 999999/7 \times p(7\times 20408+1)\\ &= p^2 \times 999999 \times (20408+1/7)\\ &= p^2(10^6-1)\times(20408+1/7)\\ &= 20408p \times 10^6 - 20408p + 142857p^2\\ &= 20408p \times 10^6 + 122449p^2\end{aligned}$$

The number will thus consist of two blocks, namely, 20408p (the first six digits) and $122449p^2$ (the last six digits, though a carry to the last digit in the earlier block is possible). If we now halve the number and add the halves together we get $20408p^2 + 122449p^2 = 142857\,p^2$

As we saw earlier, the result must be one of the cyclic arrangements of 142857, except that the carry should be added to the units digit. But the carry will not matter since it will later be added up anyway when we reduce our result to a six digit number.

P. V. P.

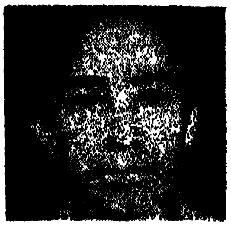
The doodling professor

MY doodling friend, Prof Longnumber, had found a curious property of some numbers. When the digits of these n-digit numbers are raised to the power n and summed together, the result is the number itself' He had reported 7 of these numbers (SCIENCE TODAY, August 1981, p.39) and maintained that there were at least 15 other such numbers of up to ten digits. Prof Longnumber's other numbers are: 153, 370, 371, 1634, 8208, 54748, 92727, 1741725, 4210818, 9800817, 24678050, 24678051, 146511208, 472335975, and 534494836.

K. N. GORDHANDAS

Mr. Gordhandas is a mining engineer in Bombay.

MEDICAL ENTRANCE



Sunil Kumar Bansal

1st In Medical Entrance Delhi '77

Raghavendra Goswami

1st in Medical Entrance Wardha '77

Bhupinder Bhandari

1st in Medical Entrance Delhi '78

Rajiv Verma

2nd in Medical Entrance Delhi '78

Sanjay Nijhara

2nd in C.P.M.T. (U.P.) in 1979

Pradeep Mehra

3rd in C.P.M.T. (Pb.) in 1980

Jaideep Bhaduri

8th in J.E.E. West Bengal in 1980

Rohit Sehgal

2nd in Roorkee Engineering in 1980

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TELL US...

...why people suffer from allergies?

EVER heard the story of the over-enthusiastic servant who tried to kill the fly sitting on the king's nose—with a machete? Allergies constitute a similar phenomenon: a system devised by nature primarily to protect the human body turns over-enthusiastic and, instead, brings discomfort to it. That is why they are also known as "hypersensitivities".

Mammals, particularly humans, are endowed with a unique mechanism which defends the body against disease-causing infections. This mechanism, known as immunity, is responsible for the manufacture of a special class of proteins in response to an invading foreign substance. These proteins are called antibodies and the foreign substances that trigger the synthesis of antibodies are known as antigens. The antibodies are highly "specific" to the antigens, that is, antibodies to antigen A are useless against antigen B, although structurally both the antibodies are not dissimilar. As a result of this specificity, the antibodies can bind strongly to the specific antigen and inactivate it. If the antigen is present on a disease-causing organism, this binding of antibody becomes fatal to it.

The antibodies belong to a class of proteins collectively known as immunoglobulins, (Ig for short). Of these, the IgE type of antibody is usually the culprit for bringing on allergic disorders. Allergic antibodies are called "reagins" and are made by people who are allergic in response to weakly antigenic, normally harmless, substances—the allergens. The reaginic antibodies have a strong affinity for fixation to mast cells in skin or mucous surfaces. No harm results when a person encounters an allergen for the first time but reagins form and bind to mast cells. When the allergen enters the body for the second time, it latches on to the cell-bound reaginic antibody. This antigen antibody union lets loose a complex chain of reactions, resulting in the rupture of mast cells with explosive disintegration of the granules stuffed inside. This in turn leads to the release of some powerful pharmacological agents which include histamine, aerotonin and heparine.

Histamine dilutes the small blood vessels, allowing excessive amounts of fluid to leak through. This causes swelling. It also contracts muscles inside the bronchial tubes of the lungs, leading to their constriction. Consequently, the person finds it difficult to breathe. Asthmatic attacks result. A few other mediators which have not yet been fully characterised are also released. These include slow reacting substance (SRS-A) or platelet-activating factor (PAF) which as the name suggests, activates the platelets. Platelets are the little pieces of cytoplasm floating in the blood that are vital to blood clotting. These chemicals are responsible for severe inflammation.

Although the biochemical events leading to the explosive fragmentation of the mast cells and subsequent release of pharmacological mediators have now been worked out it still remains a mystery why the union of antigen and antibody occurring at the cell surface should initiate this chain of events. One viewpoint holds that this mechanism was devised in order to deal with the parasitic or bacterial infections, so that the causative organism can be effectively dealt with by bringing in the helpful "granulocytes". The granulocytes are attracted by inflammation as well as the attractant properties of the released chemicals. If so, the reaginic antibody seems to be a perversion of this beneficial device.

Nearly ten per cent of the population suffers from allergies of one sort or the other. Airborne extrinsic allergens like pollens or mites in the dust can cause hay fever which is accompanied by itchiness in the nose and eyes, inflammation of the mucous membranes lining these organs and excessive mucus formation. It may take the more severe form of asthma where the delicate mucous linings of the air passages in the lungs are affected. Here, too excess mucus formation occurs and that is why the asthmatic patient coughs up thick sputum.

Allergens can come in the form of foodstuffs, too. Those sensitive to delicacies such as strawberries or shell fish suffer from urticaria, resulting in a swollen appearance. Some allergens enter through the skin on contact. These, too, can cause any of the above symptoms or bring about the formation of hives itchy, raised, angry-looking lumps in the skin, which disappear after a while. A very acute hypersensitive reaction can cause a generalised "anaphylactic shock", and, occasionally, even death. There are cases where a mere bee-s-sting has resulted in death due to such a strong anaphylactic reaction to the toxin in the sting. Fortunately, such instances are rare.

Histamine is also released wherever tissue is damaged. The body has an enzyme, histaminase, which controls the levels of histamine. It seems that allergic patients are deficient in histaminase and hence cannot take care of its excessive secretion. However, there is a fairly strong hereditary tendency towards allergic disposition. This does not mean that a person is susceptible to the same allergen as his parents, but there usually is a family history of hypersensitivity of one form or another.
is a family history of hypersensitivity of one form or another.

Hypersensitivity to a possible allergen can be determined by what is commonly known as a skin test. In this, the suspect allergen is introduced just under the skin in the forearm in minute quantities that are unlikely to cause the discomforts accompanying a full-blown anaphylactic response. But this amount is sufficient to trigger all the initial reactions resulting in redness or swelling in a short time.

Presently, there are three ways ways. The simplest is avoidance of the allergen if it can be identified. When an allergen is present in the atmosphere it may not be possible to avoid it. In such cases, antihistaminic drugs are given to counter the effects of histamine release. Alternatively, other drugs, like epinephrine, which prevents the release of the pharmacological mediators are prescribed. There is a third method, known as desensitisation. In this, the patient is initially given very tiny doses of the allergen which cause no harm. Gradually, the dose is increased till the patient acquires tolerance to the doses which had previously caused severe problems.

Yet another form of allergy which is mediated, not by the IgE antibody, but through another type of antibody, the IgG, is known as immediate hypersensitivity. In this, the allergen on entry binds to the specific IgG and this freely circulating antigen-antibody complex activates a group of proteins present in blood (collectively known as complement) thereby attracting the polymorphonuclear leucocytes, a kind of white blood cells. On contact with the complex, these cells release tissue-damaging enzymes resulting in inflammation or swelling. Alternatively, the antigen-antibody complex can cause aggregation of platelets which can either bring about secretion of chemicals that affect the blood vessels or adversely disturb the blood-clotting mechanism. These reactions are manifest in a relatively short time, whence comes the name "immediate hypersensitivity". Most of the hypersensitivities to drugs like penicillin belong to this category. At times, although rarely, hypersensitivity can be so severe as to cause death, unless prompt restorative action is taken.

Allergies can thus be seen as a beneficial protective system gone haywire.

G. P. PHONDKE

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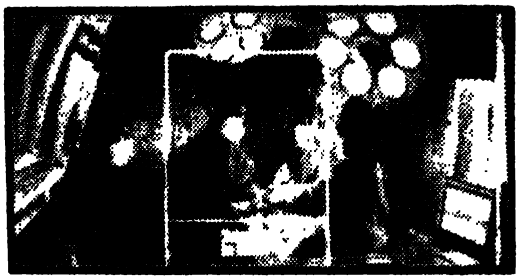

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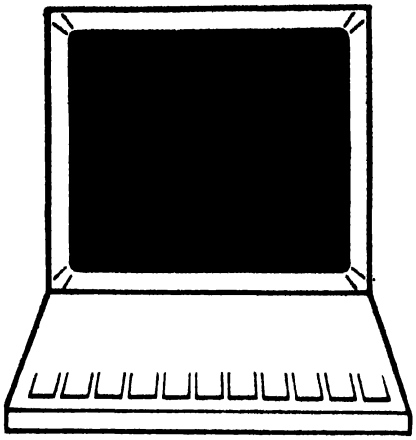

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Creative Unit-4969

Undervoltage alarm for cars

THIS is a fully solid-state undervoltage alarm for cars. It gives an audio alarm when the battery voltage of the car drops below 10 volts. The device can be used with any car having positive or negative ground system with 12 volt battery.

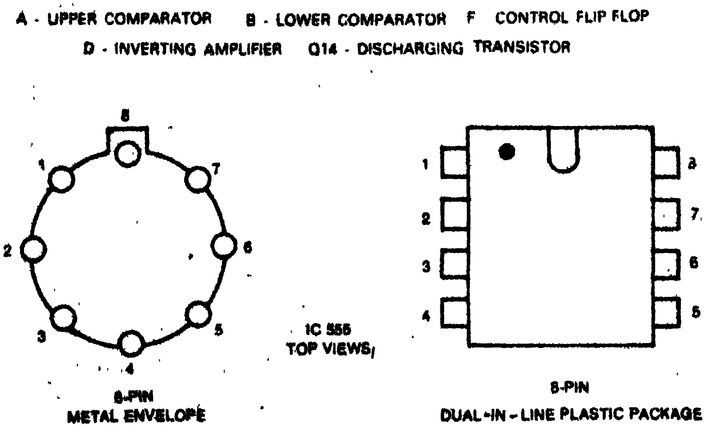
The device uses one integrated circuit, two transistors and a few other components. For ease of understanding, the circuit can be divided into three parts, viz undervoltage sensing circuit, an astable multivibrator using IC 555 and loudspeaker driving circuit using a medium power transistor 2N5294. An additional alarm-reset circuit using a SCR 2N1599 is also shown in the diagram. When the alarm starts, one can reset the alarm just by pressing the reset push-button.

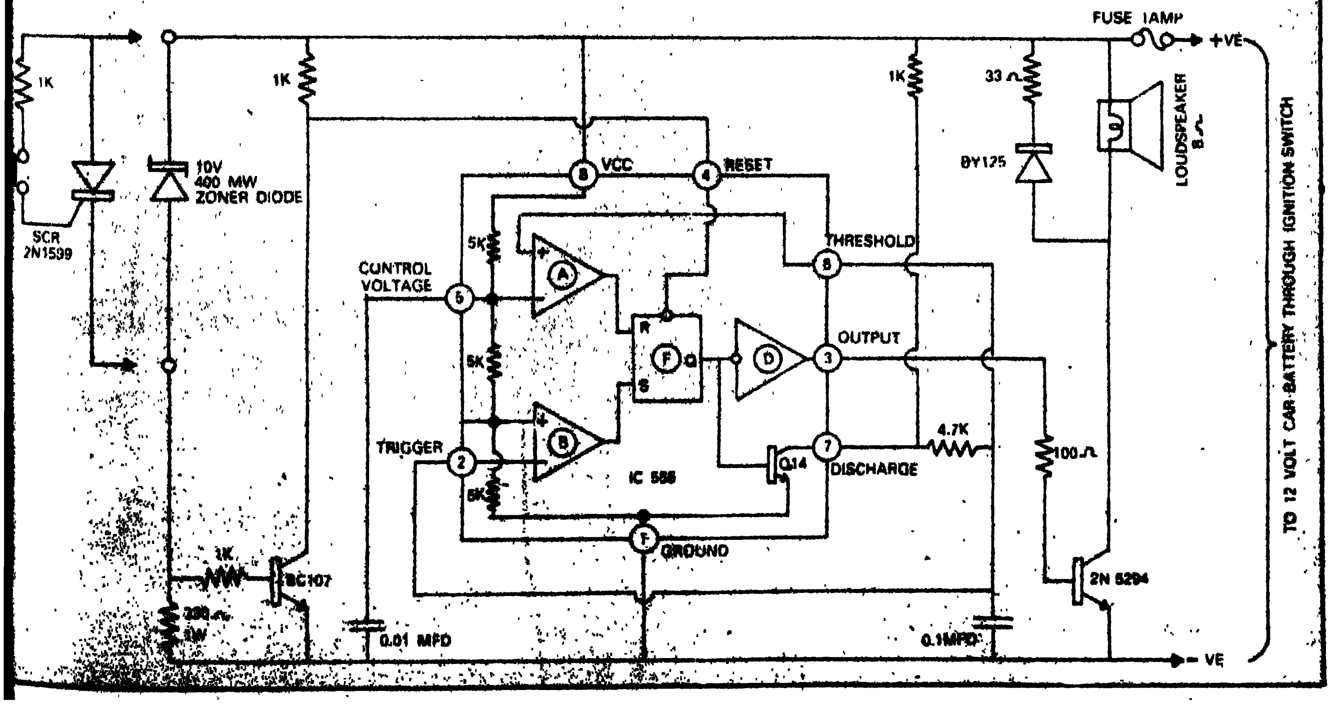
When the car battery voltage is 10 volts or more, the 10 volt zener diode comes into conduction. The resultant current through the 330 ohms resistor develops sufficient voltage to drive transistor BC 107 into saturation and the transistor in turn clamps the reset terminal of the IC 555 to ground. This makes the IC astable multivibrator unoperative.

Whenever the battery voltage falls below 10 volts, the 10 volt zener diode becomes non-conductive. Thus, the transistor BC 107 cannot keep the reset terminal of the IC 555 clamped to ground and the IC 555 goes into astable operation, as explained below.

The IC 555, used as an astable, ie free-running multivibrator has its trigger terminal 2 connected directly to the threshold terminal 6. Thus, to start with, the 0.1 mfd timing capacitor has no charge over it. This triggers the lower comparator which, through control flip-flop and inverting amplifier, drives the output high and simultaneously makes the discharging transistor Q14 non-conductive. This causes the capacitor to charge through the 1K and 4.7K resistors. When the capacitor charges to 2/3rd Vcc, ie the threshold level of the upper comparator, it resets the flip-flop, which in turn drives the output to its normal low state and brings the discharging transistor back to conduction. As the terminal No. 7 of the IC is now clamped to ground through the discharging transistor, the timing capacitor, instead of charging, starts discharging through 4.7 K resistor. The voltage across the timing capacitor falls. When the voltage falls to 1/3rd Vcc level, the lower comparator gets triggered and once again changes the state of the output and discharging transistor. This causes the capacitor to charge again. This completes one cycle and initiates the next.

The process continues, making the capacitor charge and discharge to 2/3rd Vcc and 1/3rd Vcc levels, respectively. The circuit goes through about 1500 cycles of operation per second. The repetitive high and low going output provided by this stage drives the loudspeaker-driving transistor and the loudspeaker produces an audio alarm.





The SCR alarm-reset circuit is for resetting the alarm after you have noticed the battery undervoltage condition. By pressing the reset push-button, the normally non-conducting SCR gets the necessary trigger current through its gate-cathode path and comes into conduction. The resultant current through the anode-cathode path of the SCR flows through the 330 ohm resistor. This drives the transistor BC 107 into saturation and the reset terminal of the IC 555 gets clamped to ground and the alarm goes off.

As you already know, the SCR once brought into conduction remains in conduction till its anode current is interrupted by some external means. Thus, when the reset push-button is pressed, the SCR comes into conduction and remains in conduction till the ignition switch is switched off. When the car is started again the alarm will also start, provided the undervoltage condition also exists.

You will need

Semiconductors: Integrated circuit IC 555 - 1 No.; Transistors: BC 107 - 1 No.; 2N5293 to 2N5296 (any one) or any other equivalent silicon NPN medium power transistor - 1 No.: Diode: BY 125 - No.;

Zener diode: 10V 400 mW - 1 No.; SCR 2N1596 to 2N1599 (any one) - No.

Capacitors: Ceramic or polyester: 0.01 mfd - 1 No.; 0.1 mfd - 1 No.

Resistors: 330 ohms - 1W - 1 No.; (All others half-watt type.) 4 7K - 1 No.; 1K - 3

Nos.; 100 ohms - 1 No.; 33 ohms - 1 No.
Loudspeaker: 8 ohms—1W

Approximate cost of the above electronic components in Bombay market, Rs. 60.

Misc.: Fuse 1 amp with holder, solder wires, screws, suitable enclosure, normally open push-switch, connector, IC experimenter's veroboard, etc.

ANIL V. BORKAR

BRAIN TEASERS

Square:

Find out two different digits (other than zero) such that the difference between the sum of their squares and their product is a square.

V. A. SHENAI

(Solution next month)

Solution to last month's Brain Teaser

The gardener's dilemma

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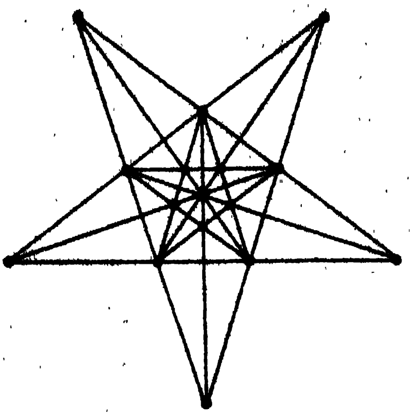

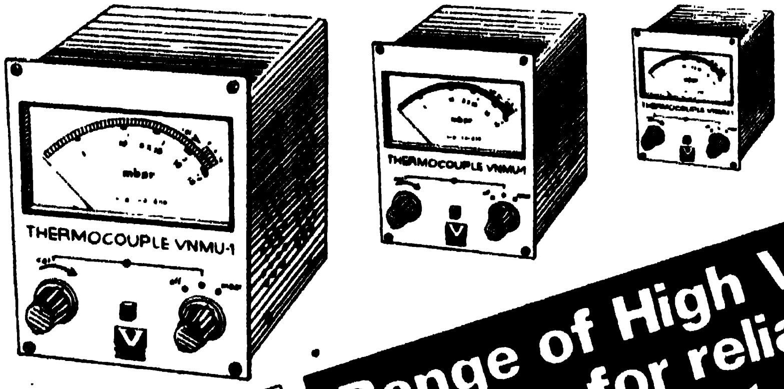

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AWARDS AND APPOINTMENTS

Magsaysay Award for "Jaipur foot" designer

DR. Pramod Karan Sethi has been named winner of the 1981 Ramon Magsaysay Award for community leadership. The Award foundation cited Dr. Sethi's achievement in improving on the elaborate and expensive artificial limbs developed in industrial countries, which had not been found to meet the needs of amputees in India's rural areas. The artificial leg, called "Jaipur foot", devised by Dr. Sethi and his associates, has enabled crippled and poor rural folk to farm and climb trees and to lead productive lives. Dr. Sethi is head of the Department of Orthopaedics at the SMS Hospital, Jaipur.

Using age-old casting methods, Dr. Sethi and craftsman Ram Chandra produced a die which enabled them to produce an artificial foot that would respond more like a real one. Small entrepreneurs helped in producing the Jaipur foot by retreading truck tyres.

The award, named after the late Philippines President, Mr. Ramon Magsaysay, carries a cash prize of $20,000.

Award for R.V. "Gaveshani"

R V "Gaveshani", the floating laboratory of the National Institute of Oceanography has been given the excellence award for 1979-80 by the India Meteorological Department. The award is given to a ship which transmits important weather observations expeditiously to the nearest coastal radio station, enabling weather forecasters to locate and track storms.

INSA awards for young scientists

TWENTY scientists aged below 32 have been selected for the 1981 Indian National Science Academy awards for their achievements in various disciplines; each will receive a cash award of Rs. 5,000 along with a medal. They may also be considered for grants to enable them to continue research in their fields of specialisation.

The following are the awardees.

Dr. B. K. Chaudhuri (Indian Association for the Cultivation of Science, Calcutta); Mr. R. N. Chatterji (University of Calcutta); Dr U. C. Das (National Geophysical Research Institute, Hyderabad); Dr. J. B. Joshi (University of Bombay); Mr. C P. Katti of New Delhi; Dr. B. D. Kulkarni (National Chemical Laboratory, Pune); Dr. V K B Kota (Physical Research Laboratory, Ahmedabad); Dr. A C. Kunwar (Raman Research Institute, Bangalore). Dr. A. K Lala (Indian Institute of Technology, Bombay); Dr. Kukhada Mohandas (Sugarcane Breeding Institute, Coimbatore); Dr N. Nagendra (Osmania University, Hyderabad); Mr. Prakash Nagarkatti (Defence Research and Development Establishment); Dr. R. Nagaraj (Regional Research Laboratory, Hyderabad); Mr. D. Pain (Indian Instituete of Experimental Medicine, Calcutta); Dr. S. M. Srivastava (Indian Statistical Institute, Calcutta); Dr. K. B Sainis (Bhabha Atomic Research Centre, Bombay); Dr. Kuldip Singh Sidhu (Punjab Agricultural University, Ludhiana): Dr. R. D. Tripathi (University of Gorakhpur); Dr. K. P. R. Vittal (All-India Co-ordinated Research Project for Dryland Agriculture, Hyderabad) and Dr. R. L. Yadav (Central Institute of Medicinal and Aromatic Plants, Lucknow.)

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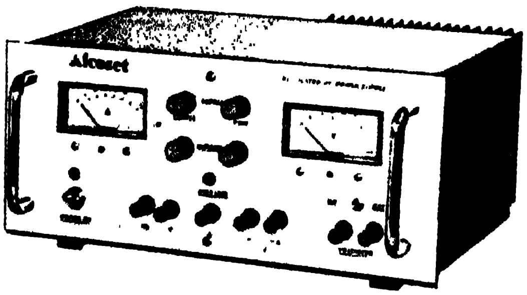

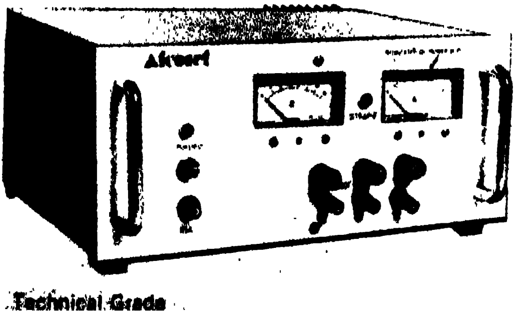

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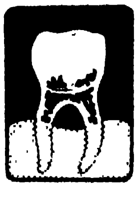
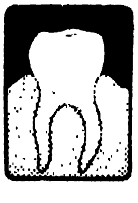


Dentists say that if teeth are not cleaned properly a thin layer of bacteria called plaque, which forms around your teeth and gums, starts accumulating. This leads to tartar which weakens and pushes away gums causing even healthy teeth to fall out. Gum troubles can also harm health in general.

Forhan's protection for the gums



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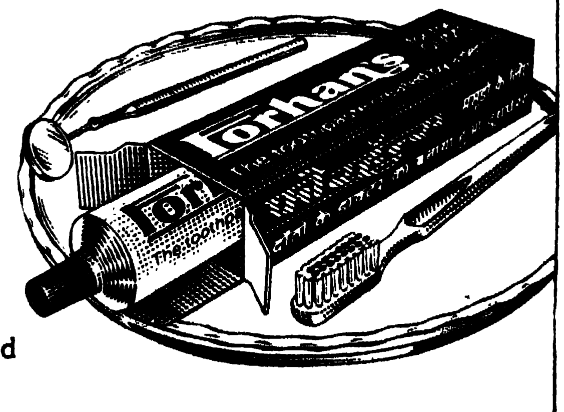

Forhan's For the gums

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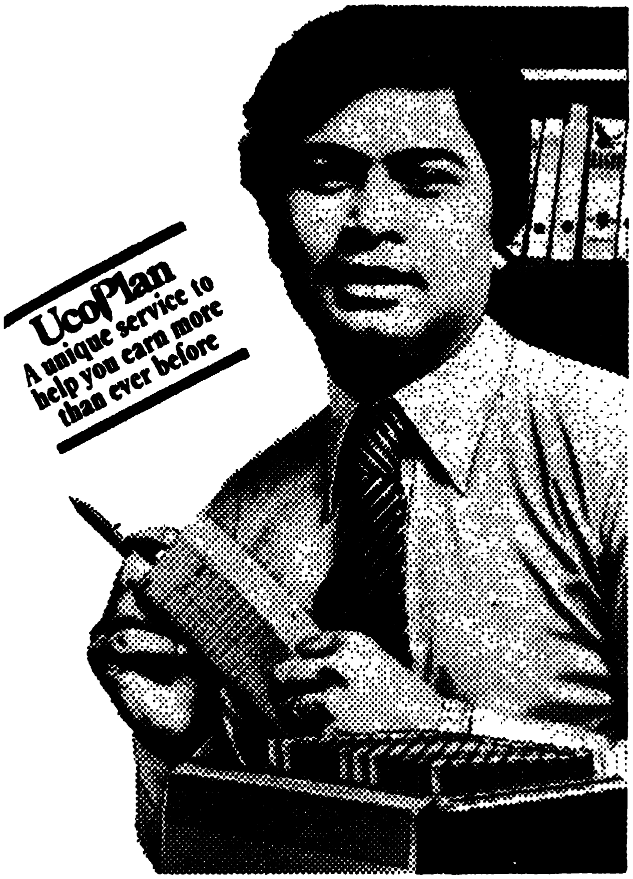
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MEETINGS CALENDAR

November

1-2: Environmental pollution, control and water conservatio seminar, Patna (Dr. Janardan Jha, Convener, Prof. of Ci Engineering, BIT, P.O. Sindri Institute, Dist. Dhanbad, Bih 828 123)

2-5: Application of informatives for South and Central As Rawalpindi, Pakistan (B.Raj Bhandari, Administrative offic UNESCO House, 17 Jor Bagh, New Delhi-110 003)

16-20: Estuaries—their physics, chemistry, biology, geolog geophysics and engineering aspects, Dona Paula, Goa (B.R Bhandari, UNESCO House, 17, Jor Bagh, New Delhi-110 00

23-26: Asian mining, int. conference, Singapore (The Meetin Secretary, The Institution of Mining and Metallurgy, 44 Por land Place, London WIN 4BR, England)

23-12 Dec: Microbiology of nitrogen cycling, SCOPE/UNESCO training course (Mymensingh, Bangladesh, (B. Raj Bhandar UNESCO House, 17 Jor Bagh, New Delhi-110 003)

23-25: Nutrient transport studies in animals for the purpose o milk and meat productions, symposium. Karnal (Dr. N. C Ganguli, Convenor, National Research Centre on Dairy Chemistry, National Dairy Research Institute. Karnal 132 00

23-28: Food systems of the developing world with speci reference to India, IGU symposium, AMU Aligarh (Dr. Mohamed Shafi, Dept of Geography, Aligarh Muslim Unive sity, Aligarh)

29-1 Dec.: Astronomical Society of India, 7th annual meetin University of Roorkee (Dr. Manmohan Singh, Organising Secretary, 7th ASI meeting, Dept. of Mathematics, University of Roorkee, Roorkee-247 672)

30-12 Dec.: Theoretical aspects of computer science, int., conference, Indian Institute of Science, Bangalore (Prof. D.K. Subramaniam and Prof. S.V. Rangaswamy, School of Automatio Indian Institute of Science, Bangalore 560 012)

30-12 Dec.: Hospital management, 10th Seminar, AIIMS New Delhi (P.N. Ghei, Indian Hospital Association, Nirman Bhavan, New Delhi-110 011)

30-19 Dec : Analysis and design of machine foundations, int, training programme, Roorkee, India (B. Raj Bhandari, UNESCO House, 17, Jor Bagh, New Delhi-110 003)

December

Meteorological aspects of tropical droughts, WMO symposium, New Delhi (Dr. P. K. Das, Director, India Meteorological Dept., Lodi Estate, New Delhi). (Dates not intimated)

Water quality, UNESCO/WHO regional workshop, Colombo, Sri Lanka (B.Raj Bhandari, UNESCO House, 17 Jor Bagh, New Delhi-110 003). (Dates not intimated)

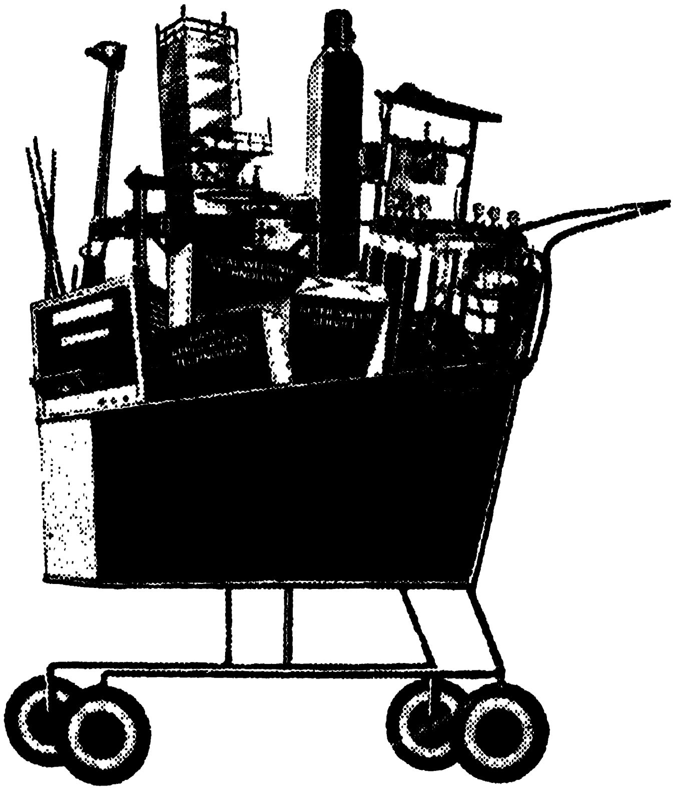
1-4: Role of laboratories in technical education at all levels, Colombo, Sri Lanka (B. Raj Bhandari, UNESCO House, 17, Jor Bagh, New Delhi-110 003)

2-3: Mechanisms and Machines, 1st national conf., Indian Institute of Technology, Bombay (Dr. C. Amarnath, Organising secretary, NACOMM-81, Mechanical Engineering Dept, Indian Institutes of Technology, Powai, Bombay-400 076

3: Association for engineering education in South and Central Asia, Colombo, Sri Lanka (B. Raj Bhandari, UNESCO House, 17, Jor Bagh New Delhi-110 003)

The venue of the 4th All India Congress on cyctology and genetics to be held from 17 to 21 October is Bhagalpur and not Hyderabad as reported earlier (Science Today, July 81, p.71).

THE TECHNOLOGISTS' SUPERMARKET



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IF...

... atmospheric carbon dioxide kept growing

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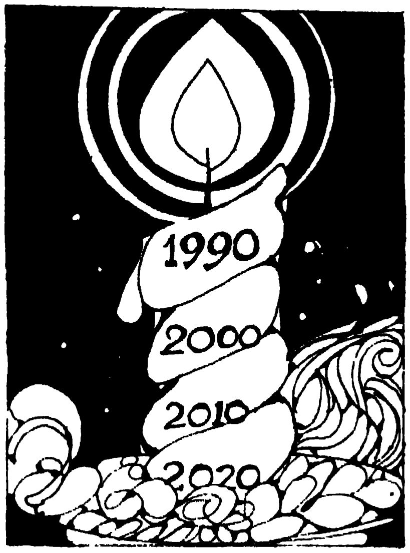
The increased heating of the atmosphere would result in catastrophic floods and climatic changes The rise in temperature would be maximum at the North Pole since it has no stabilising land mass, and minimum at the equator. The progressive increase in atmospheric temperature due to the so-called "greenhouse effect" would lead to the melting of arctic polar ice, and the antarctic ice sheet and glaciers, resulting in a rise in ocean levels and extensive flooding of rivers This would cause submerging of many land areas, especially coastal cities and towns, with considerable loss of life and property

Distress flood signals would be the order of the day in coastal towns. This may continue for almost a decade after the onset of extensive melting, followed by slow melting for hundreds of years. The initial rise of 5 to 10 metres in the sea level would continue with a maximum rise up to 80m when all the ice has melted. This would change the map of the world with many important cities fully submerged, and some nations becoming 'extinct'. All this may sound like science fiction, or a flashback from the flood story in the Book of Genesis, but as we shall see below, we are talking of a *possible* situation based on scientific models of the atmosphere perturbed by man.

If the burning of fossil fuels by man continues at a growth rate of 4 per cent per year, it is estimated that doubling of atmospheric carbon dioxide would be reached in the year 2030, and it would give an increase in global average temperature of probably 1.5° to 3°C, with a likely maximum increase of 8°C at the North Pole. This increase is very significant, because the naturally occurring normal fluctuations in the temperature of our atmosphere today are only within half a degree centigrade. An average temperature increase of 2° to 3°C is sufficient to start the melting of ice and continue the process with further rise of temperature. It may be said that the most serious short-term climatic problem facing mankind is the increasing percentage of carbon dioxide in the atmosphere, threatening to appear in the next 50 to 60 years, and continue for decades, even centuries.



Large atmospheric temperature increases would also trigger many other disastrous atmospheric effects. For example, the changes in north-south polar asymmetry would bring about major shifts in the atmospheric circulation pattern, resulting in large climatic variations in different parts of the world. This would change the rainfall pattern, river courses and soil structure. Inland lake levels and water supplies would be lowered rapidly and the water problem would become severe. Some arid lands may become areas of plentiful food. On the other hand, some of the well irrigated lands of today may become the deserts of tomorrow. Paleoclimatological records do bear the signatures of such changes in the past caused by natural climatic variations, including atmospheric temperature cycles, melting of glaciers and changes in the ocean level. However, large changes caused in a short span of time by human activities would be unique in the history of the human race, and in fact in the entire geological history of the Earth. Thoughtful utilisation of alternative sources of energy may, however, avert a crisis.

Let us first see how the "greenhouse effect" is produced in the atmosphere due to the presence of carbon dioxide. This effect relates to the absorption by the carbon dioxide of the long-wave infrared radiation from the Earth as a result of solar heating, leading to an increase in atmospheric temperature. The heating of the surface of the Earth leads to terrestrial infrared radiations in the wavelength regions where carbon dioxide absorbs significantly. The heating of the dry atmosphere is in fact mainly due to absorption of terrestrial infrared radiation by carbon dioxide in this region. Ozone and some polyatomic hydrocarbon gases also absorb here, but their concentrations are too low to be of much significance. Absorption of infrared radiations by water vapour is also important in the humid air The nett atmospheric temperature rise will in fact depend on many complex factors, and as such, the term "greenhouse effect", as applied to the atmosphere, is a misnomer.

The natural carbon dioxide level in the atmosphere, initially introduced through outgassing from the Earth, is maintained through its continuous formation by the decomposition of organic matter, with only small additions from volcanic sources. It also enters the atmosphere through soil, plant and animal respiration processes and the action of winds on the sea surface. The annual production by natural processes is nearly 150 gigatonnes (1GT = 10^9 tonnes), whereas fossil fuels presently contribute nearly 5 GT. It has an atmospheric residence time of about five years. The main sinks for carbon dioxide are the ocean waters and photosynthesis, which also help in maintaining a fixed concentration of the gas in the atmosphere. However, the capacity of oceans to take up excess carbon dioxide is

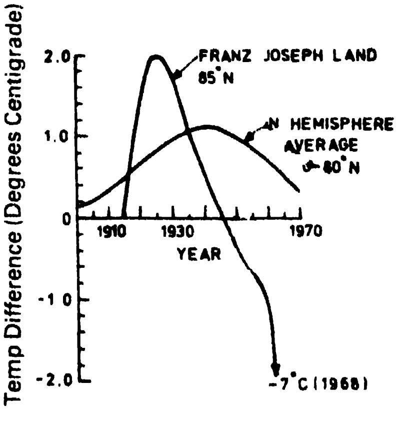


Fig. 1: Mean atmospheric temperature change for the northern hemisphere and for a single station (F. J. Land) with large temperature difference (Lovelock, J. E., 1971)

limited by the pH (acidity/alkalinity) of the surface waters. With continued use of fossil fuels, the fraction going to the oceans would decrease and the build-up in the atmosphere would be faster than in the past, because mixing of the surface waters with the deep oceans is very slow compared to the rate of increase in carbon dioxide.

At the turn of the century, when the combustion of fossil fuels was very small, the natural concentrations of carbon dioxide in the atmosphere was about 290 parts per million. Due to the industrial and other man-made releases, the concentration has now increased to nearly 330 ppm It has been estimated that the concentration will rise to 400 ppm by the year 2000. It all the fossil fuels are burnt, the atmospheric concentration may rise to 1500 ppm, nearly five times the present level. Such an increase could result in large increases in the atmospheric temperature. If the atmospheric effects of carbon dioxide increase are fully established, this raises a very important question: Will it be advisable to go on burning the fossil fuels at the present rate? Once the effect has been produced in the atmosphere it will not be possible to reverse it for thousands of years. Our understanding of the problem today is very limited.

After the turn of this century, the temperatures all over the northern hemisphere were increasing, and it was firmly believed that this increase is due to increasing levels of carbon dioxide Then a cooling trend started in the year 1940. Fig. 1 adapted from J. E. Lovelock (1971) shows the mean atmospheric temperature change for the northern hemisphere since the year 1900 It also includes the trend for a single high latitude station (Franz Joseph Land, 85°C north). This station has shown extreme changes in the temperature The observed decrease in temperature since 1940 could be due to a natural temperature cycle of shorter period, masking the effect of carbon dioxide increase. The trend is likely to be reversed during the next decade. Our understanding of these short-period natural climatic cycles is still poor. There have been long-period natural climatic cycles during the last million years which started after the end of the long warm epoch in the geological history of the Earth. The climatic cycles of roughly 2,000 years, 20,000 years and 100,000 years with amplitudes of the order of 2°, 3° and 8°C respectively have been estimated. These cycles are probably caused by natural oscillations due to slow thermal interactions between the atmosphere, oceans and glaciers. The temperature rise by the continuous use of fossil fuels for energy needs can exceed even the longest-period natural cycle.

It is now fully established that our future energy strategies will have a wide range of influences on the global climate, and carbon dioxide is an important parameter to be considered. The International Atomic Energy Agency ((IAEA) and the International Institute of Applied System Analysis (IIASA) have initiated long-term studies of the problem of carbon dioxide from fossil fuels and its possible atmospheric effects. F. Niehaus who has been connected with the joint IAEA/IIASA studies of this problem has carried the projection of carbon dioxide emission, carbon dioxide concentration and temperature rise to the year 2100. Fig. 2 gives the projection for the utilisation of estimated 50 terawatts (2TW = 10^{12}W) of energy from fossil fuels based on the model developed by Niehaus (1979). Note that the temperature rise of 9°C is projected by the model, large enough for a major climatic upheaval. It is, however, likely that the predictions based on simple model of carbon dioxide heating are not valid and there may be secondary climatic feedback effects, for example, increased cloudiness due to carbon dioxide warming may cut down the solar radiation input to the atmosphere; and the increase in vegetation cover due to an increased carbon dioxide level may change the planet's albedo (reflectivity). Both of these can lower the atmospheric temperature. It is hoped that future models would be able to present a clearer picture of the problem.

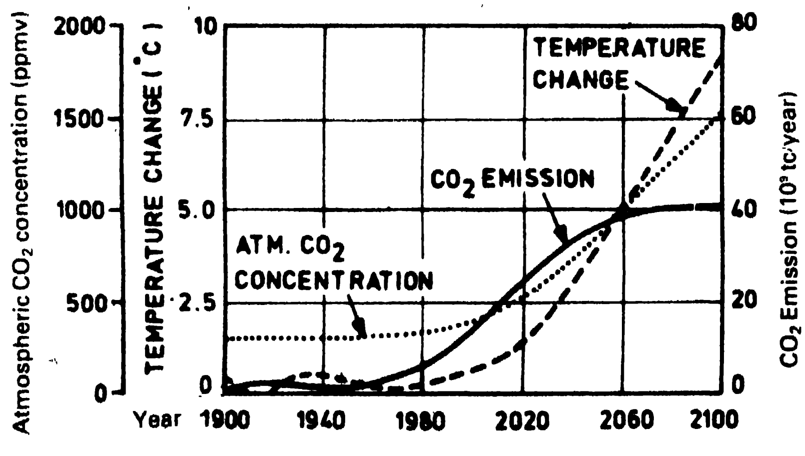


Fig. 2: Carbon dioxide impact of 50 TW fossil fuel strategy

Since the continued use of fossil fuels can lead to unpredictable changes in the global climate, it is important to consider different energy technologies to optimise their use. In addition to the carbon dioxide problems, the burning of fossil fuels and use of nuclear energy both lead to the release of enormous waste heat into the atmosphere, thereby changing its radiation balance further. The development of renewable energy resources, including solar energy, winds and tides, bio-gas and hydroelectric power, do not lead to significant changes in the radiation balance of the atmosphere The development of renewable fuel forests may provide the dual advantage in consuming the excess carbon dioxide by the fuel trees and giving a source which balances the input and output of carbon dioxide in the atmosphere. We have thus touched on a very fascinating area for future research related to energy planning with regard to the climatic impact The problems are indeed challenging and the solution must be found during the next one or two decades. It is surprising tha the energy planners all over the world have not given sufficient consideration to the to the possible effects of increasing carbon dioxide and waste heat in the atmosphere. It is certainly not economical to consider these today, but the important questions concern how much we can sacrifice for the well being of posterity, and for the perpetuation of the human race on the planet.

K. G. VOHRA

Dr. Vohra is Head, Division of Radiological Protection, Bhabha Atomic Research Centre, Bombay

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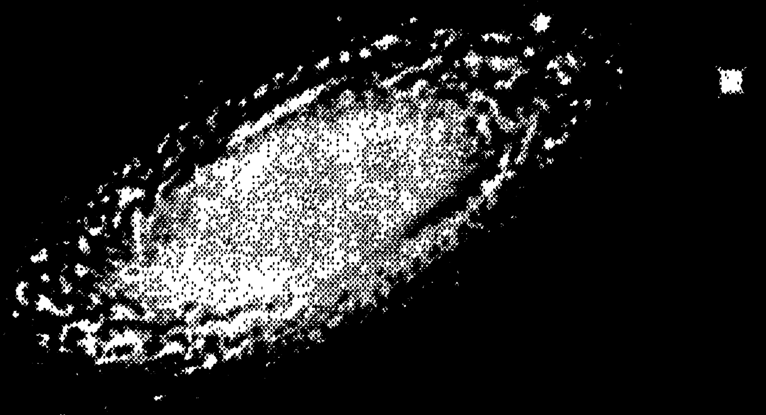

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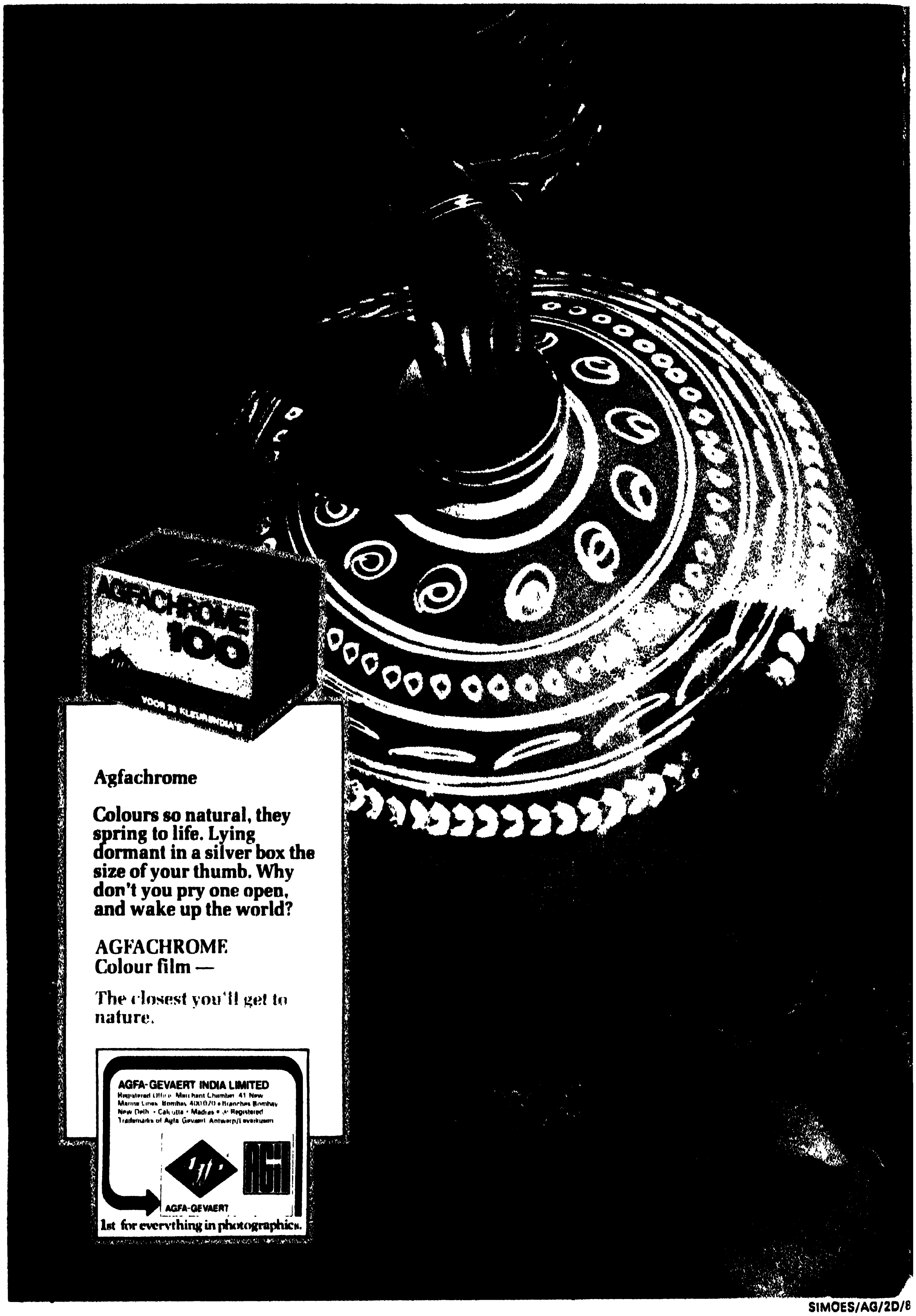

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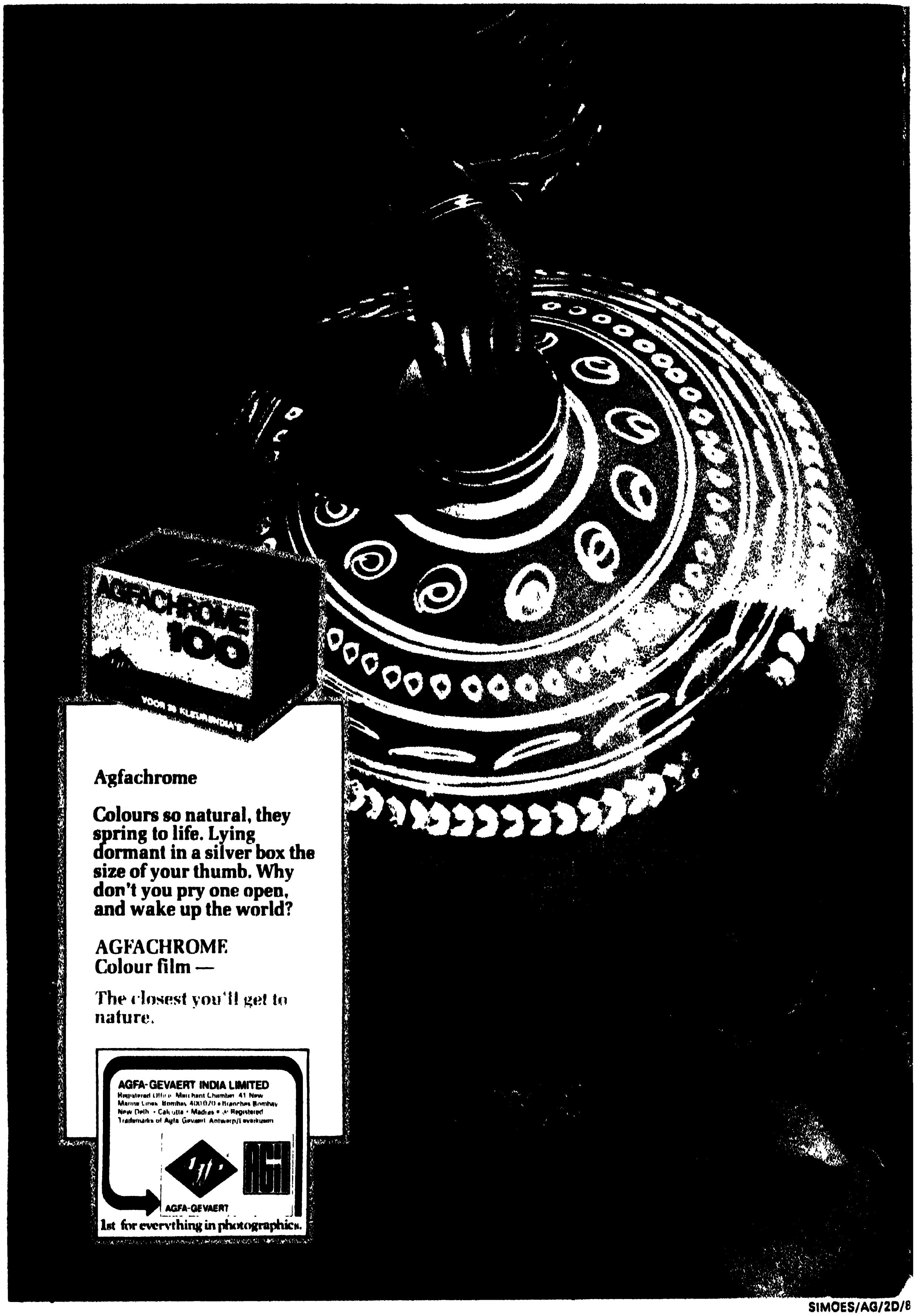

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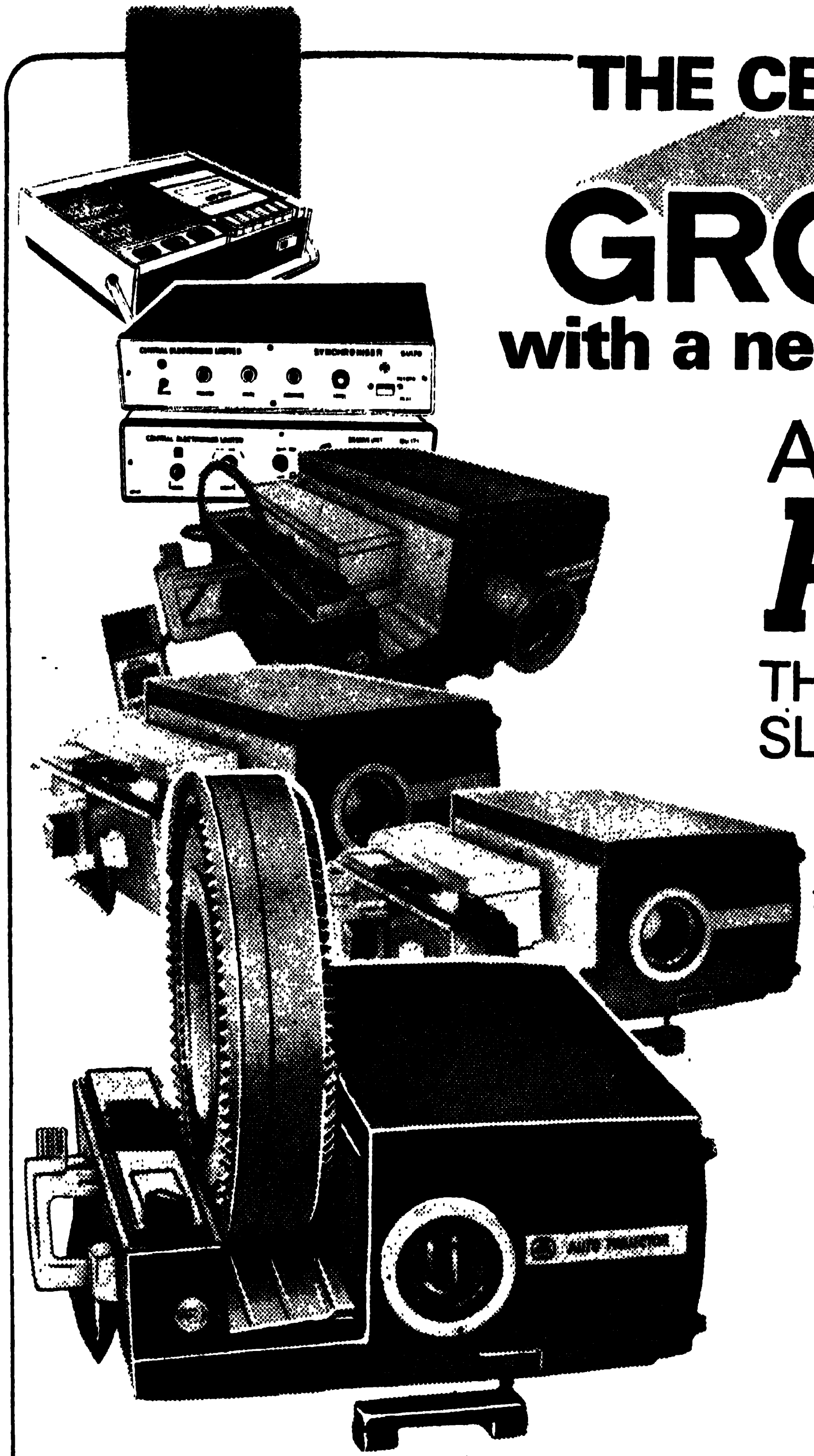

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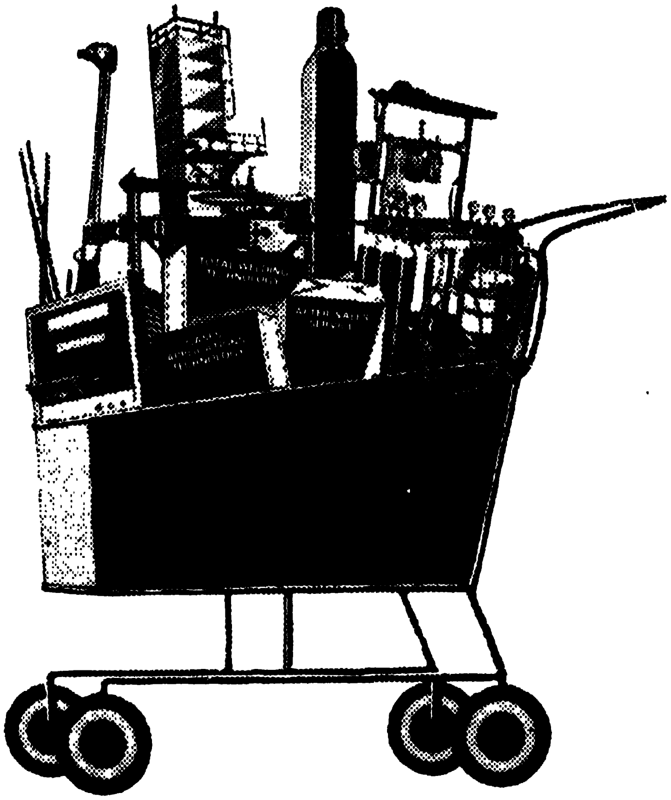

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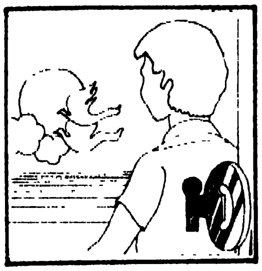

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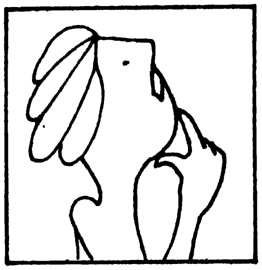

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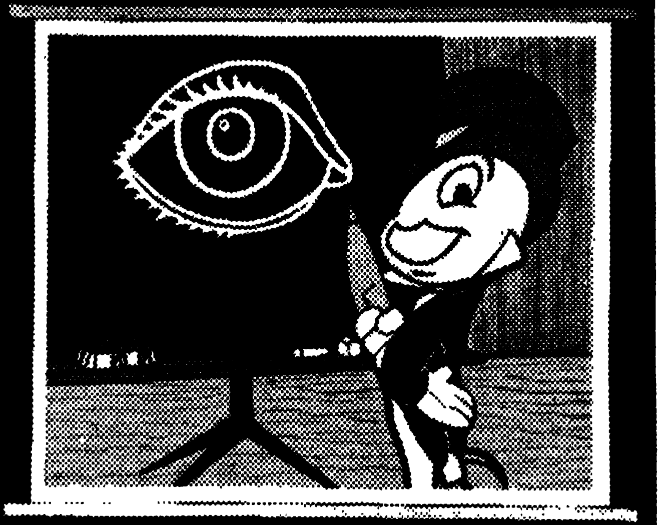

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LETTERS

INDEPENDENT RESEARCH PROJECTS FOR YOUNG SCIENTISTS

THE call given by the Society of Young Scientists to encourage young scientists has found limited, though significant, response from the Department of Science and Technology (DST) of the Government of India. Under its Science and Engineering Research Council (SERC), the department has called for preliminary research proposals in *Thrust Areas* (for details, see SCIENCE TODAY, May 1981, *Current Science* and CSIR journals). One of the highlights of the scheme is to encourage brilliant young scientists. It is, therefore, expected that young scientists working in DST-recognised institutions (both private and governmental, voluntary or public sector), universities or even unemployed scientists (or those from abroad) will directly send preliminary proposals in the Thrust Area Programme (TAP) to the DST. The proposals must carry technical details of the proposed work including objectives, methodology and expected results. It should also carry a brief justification of the proposal and a note on the self-assessment of the candidate. The project support also has a provision for some infrastructural support, including technical staff, equipment and contingencies, besides the salary of the project-in-charge.

The most important aspect of the new scheme is that the young scientists can directly send the proposals without the routine bottlenecks of 'through proper channel' and the certificates from 'head of institutions' to allow the research project. After preliminary proposals are obtained, meetings of every group of proposing (in a given thrust area) scientists will be convened to discuss the logic of each project and the projects will be decided on the basis of its merit and not on the seniority of the scientists. The meeting will obviously be attended by all the young and old scientists together and they will have to justify and defend their projects in the open meeting.

Young scientists from India (and Indians abroad) who want to work independently should submit proposals to the DST and defend these on their merit. They must also collectively ask for encouragement to younger scientists by DST, giving preference to those young scientists who do not have any projects in hand over those who already have several projects in the same and/or other areas. Such people, obviously, act only as 'managers'.

For details kindly write directly to . Dr. Ashok Jain, Principal Scientific Officer, Department of Science & Technology, Technology Bhavan, New Mehrauli Road, New Delhi 110016.

N. N. MEHROTRA

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GOLDEN RECTANGLES

THE "golden rectangle" is said to consist of Fibonacci numbers for its sides ("The fascinating Fibonacci numbers", July, 1981). But, in the book *Mathematics* published in the *Time-Life* series, the golden rectangle is defined as one in which the longer side is equal to the diagonal of the square on the shorter. Ancient Greek and Roman buildings are claimed to be golden rectangles of this type. Which is true?

K. G. RAMANNA

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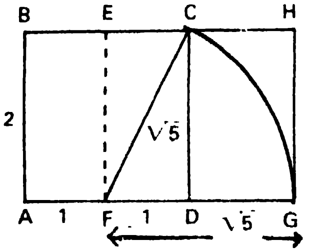
Basil Davis writes: *It is inaccurate to say that the golden rectangle consists of Fibonacci numbers for its sides. As stated in my article, the sides are in the golden ratio—the ratio approached by consecutive Fibonacci numbers as the numbers become extremely large. This equals $(1+\sqrt{5})\ 2$ or 1.618... A rectangle whose sides are Fibonacci numbers is only approximately a golden rectangle. The approximation becomes better as the numbers become larger.*

The Time-Life *book* Mathematics *defines the golden rectangle as one in which the longer side is equal to the diagonal of the square on the shorter. On page 94 (1963 edition), we read: "The ratio—expressed more precisely as 1 : 1.618—occurs in pentagons, circles and decagons—but notably in the golden rectangle, a figure whose two sides bear the magic relationship to each other." The following diagram of a golden rectangle (without the numbers) is given on the same page.*



ABCD is a square. F is the midpoint of AD. FC = FG. AGHB is a golden rectangle.

From elementary geometry we see that $AG/AB - (1+\sqrt{5})/2 = 1\ 618$...

A rectangle satisfying the definition stated by Mr. Ramanna would have its sides in the ratio $1 : \sqrt{2}$ or 1 : 1.414.

Two additional facets of Fibonacci numbers may interest your readers. As the article points out $F_{2n+1} = (F_n)^2 + (F_{n+1})^2$. It can also be seen that $F_{2n} = (F_{n+1})^2 - (F_{n-1})^2$. These two relationships make it possible to calculate F_n without going through F_1 to F_n successively; F_n can be expressed as the sum or difference of the squares of two other F-members, each less than F_n; and each of these, in turn, can be similarly expressed till we come to the first two F-numbers 1 and 1. By no means less cumbersome, the process, however, is interesting.

The other facet is a general series of which the Fibonacci series is a special case. The general series is $F_n = K(F_{n-1}) + F_{n-2}$. In the Fibonacci series, K = 1. Let us take the case where K = 2. The numbers will then be 1, 1, 3, 7, ... Each number is multiplied by two and added to the previous number to obtain the next number. The beauty of this is that F_n/F_{n-1} tends to be equal to $(2+\sqrt{4+2^2})/2$. In general, F_n/F_{n-1} tends to $(K+\sqrt{4+K^2})/2$.

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RAMANUJAN'S WILL

THE Sunday (21 June) edition of *The Hindu*, Madras, published an article "Ramanujan's Last Will And Testament", which carried a photograph of the "old dilapidated house" in Madras in which Ramanujan lived and also the photograph of his 81-year-old widow, Janaki Ammal. It seems Janaki Ammal has been offered only a pittance of a pension and the old house has been left neglected. This is unfortunate. The authorities must do something for the house and the aged widow, at least to keep the memory of the great mathematician.

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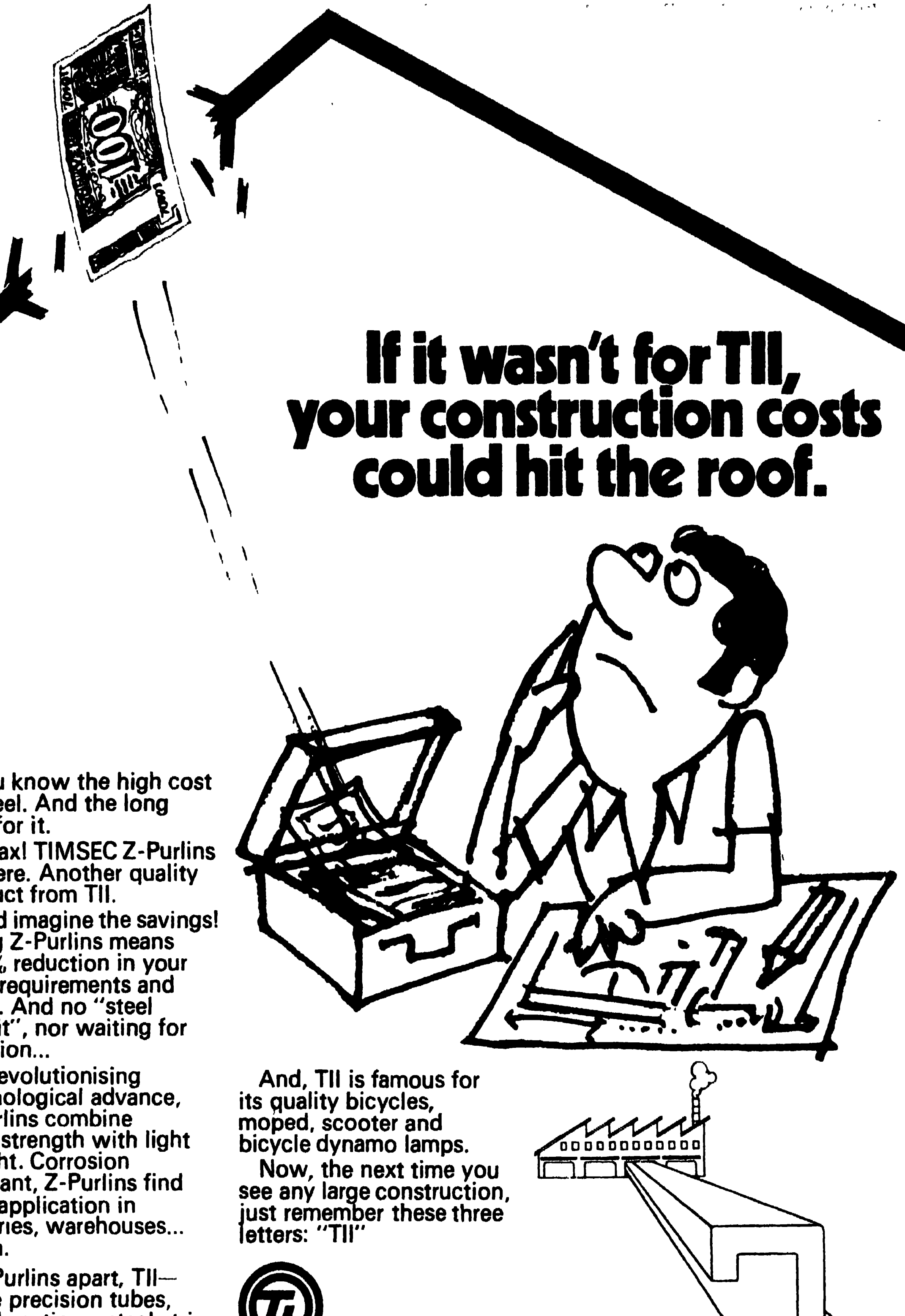

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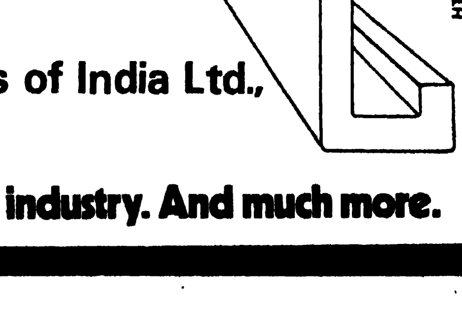

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Manpower for information

INFORMATION is an invaluable input in all national developmental activity. And the application of technology to information handling is ushering in a total revolution in information communication. The Universal Information System in Science and Technology (UNISIST) and other international and regional programmes are accentuating the necessity for developing global information exchange systems. No wonder then that a growing awareness of the pervasive role of information has set many countries to examine seriously the need for systematic planning in organising information for effective use. The industrially advanced countries are already engaged in realigning and restructuring their existing information resources and facilities and utilising technology to the full in order to achieve a greater effectiveness and efficiency in their information systems and services. Developing countries, too, are striving, though slowly, to create national information infrastructures.

In India, the Report of the Working Group on Science and Technology for the Sixth Five-Year Plan recognises information as a resource worthy of care, organisation and management. It explicitly emphasises the need to create an effective infrastructure for scientific and technological information (STI) But the question is, do we have all the capabilities, at present or in the near future, to create the systems and services that would make information a factor of production? One of these, a factor that contributes substantially to the success of any system, is the adequate and continuous supply of qualified manpower at all levels—in this case, the information personnel. We shall require them to plan, design, develop, operate and evaluate our information systems and services. This is one of the most important parts of planning for a national information system.

The types of service institutions that together constitute the total national information system determine the manpower requirement. Over the last quarter of a century, especially in the developed countries, the national information system that has evolved generally comprises libraries, documentation centres, information analysis centres, data bases, data banks, clearing houses, referral centres, dormitories stocking less used materials and such others. These institutions may operate at the national, sectoral, or even local levels, and many of them may be oriented to particular subjects, disciplines or missions.

Most of these institutions have sprung up in the context of education, higher learning, research and development, and mission-oriented activities. They offer a variety of products and services geared mainly to the requirements of these respective activities. But today the demand for information has grown much wider and more complex. Fulfilling it calls for a great deal of study and research to create new products and services for use in new and quite different contexts like those of legislation, planning, policy-making, decision-making at all levels, business and industry, rural development, information at the grass-root levels and also for the general public.

Besides this growing complexity, the idea is now gaining ground that problem-solving, the most important target in social and economic development, requires the support of a problem-oriented information system. STI, a vital component of the information base used in problem-solving processes, has then to be necessarily augmented with societal information that includes political, economic, demographic, occupational, health, legal, regulatory, sociological, cultural, and environmental information. The organising principle, therefore, for the design and development of a national information system is not merely STI but scientific, technological and societal information (STSI)

Indeed, problem-oriented information systems had begun to emerge in the late sixties and, with a growing emphasis, in the seventies, particularly in the United States. They represent a context in which information is utilised for societal problem-solving, be they problems of economic well-being, environmental protection, agricultural productivity, energy availability and use, public health and safety, or disaster prevention and control.

Private information brokers and new intermediaries of government agencies are the newly emerging institutions that offer this specialised quality of service. They are expected to repackage validated and authentic information collected from a variety of sources. This service is, of course, available only at a price. The users of problem-oriented information systems, often ill-defined, embrace a wide variety of groups—elected officials and their staff, civil servants, businessmen, attorneys, scientists, engineers, judges, market researchers, consultants, media people and local citizens.

Problem-oriented information systems are also slowly developing in India. The Small Enterprises Documentation Centre (SENDOC) of the Small Industrial Extension and Training Centre, Hyderabad, the Documentation Centre of the National Institute of Health and Family Welfare, the Council of Scientific and Industrial Research (CSIR) programmes in the fields of housing, school buildings, all-weather rural roads, sanitation, pollution hazards, etc, and the sectoral information centres for drugs, food, leather and machine tools are a few examples.

Sophistication in organising information systems and services does not relate to merely the application of technology for storage, dissemination, accessibility and speedy retrieval of information. It also relates to the intellectual effort of distilling and sifting information from a variety of sources and then evaluating, consolidating, condensing and repackaging it to suit a specific situation.

So if we ought to plan, design and develop versatile information systems and if information ought to function as a factor of growth and development, highly skilled manpower is essential and so is manpower planning. Four groups of information personnel, namely, librarians, documentalists and information scientists, subject specialists with particular skills in information consolidation and repackaging, and system analysts are mainly involved in the organisation and management of the different types of institutions mentioned earlier which make up the total information system. There are other groups too, such as information generators (researchers, scholars, etc), translators, editors, referees, publishers, printers and reprographic and micrographic specialists who are involved in the information transfer process. I shall, however, focus attention only on the four main groups identified above.

Libraries and documentation and information centres are the only types of information institutions that have been operating in India; the other types are yet to be created. They do offer traditional library and documentation services but cannot match the quality of services available in the more advanced countries. Initiatives, however, have been taken by some institutions to develop computerised information services and also information analysis and repackaging services.

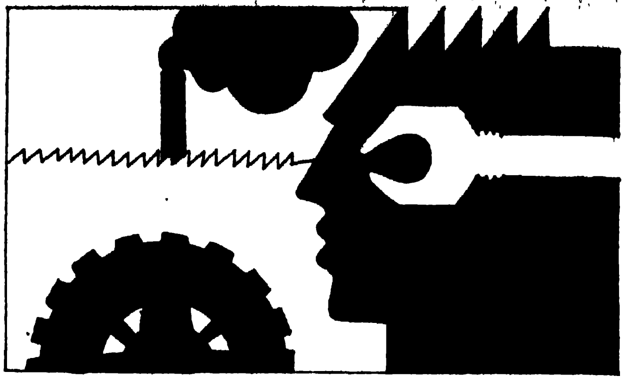
Organising and managing information systems and services in India come up against a major problem. Scientific and technological information, almost in its entirety, has to be imported. This poses serious difficulties, not only in building up an information base, but also in coping with the rapid changes taking place in information communication as technology plays an increasing and major role. The problem becomes particularly serious since we are totally unprepared for these changes. If we are to redesign our information systems and services to keep pace with these changes, the implications for manpower development are enormous.

Manpower for our libraries and documentation and information centres presently comes from about 50 library schools run by the universities and two specialised information science programmes offered by the Documentation Research and Training Centre (DRTC) of the Indian Statistical Institute, Bangalore, and the Indian National Scientific Documentation Centre (INSDOC) of the CSIR, New Delhi. Those from university schools are largely absorbed by the academic institutions while DRTC and INSDOC trainees go to research and development institutions, private and public industrial undertakings and government departments. On an average, about 1,800 candidates undergo professional training every year to be fitted into these different levels.

A majority of university library schools, barring a few progressive ones, seem to be totally oblivious of the sea change that has taken place in the generation, production, dissemination, distribution and use of knowledge. The personnel turned out, quite naturally, do not measure up to the quality of services that is needed. A drastic change in the approach, attitude and motivation is necessary, besides changes needed in the syllabi offered, their contents and hands-on practical field training. Students should be introduced to computers at the first professional degree. The over-emphasis on techniques should give place to an emphasis on services and the contents of the syllabi should be weighted in favour of information sources and media, their ramifications, growth, development and use. These changes also require a machinery to implement them, though slowly but surely.

Though the library schools must bear a major share of responsibility for this state of affairs, the entire blame cannot be laid at their doors. Even the faculty members of many library science departments are seldom exposed to the new horizons opening up in the library and information field. Most also lack field experience. Their environment and atmosphere are hardly conducive to developing a more progressive approach. And the physical facilities are awfully poor. All these aspects need adequate attention if any serious change is to take place. These, and many other problems, have been discussed at a number of conferences, seminars, symposia and other meetings. Unfortunately, nothing tangible has resulted.

Librarians, documentalists and information scientists are only one segment of the manpower force. Computer system analysts, including data-base managers and operators, and subject specialists skilled in consolidating and repackaging information, form two fairly large and strategic segments. Computer specialists generally find information a fascinating and fertile field with unlimited scope for innovations. So far, however, computer applications have achieved no more than conversion of printed secondary publications into computerised data bases though, with computer netting, accessibility to information has been remarkably improved.



In fact, the more far-reaching changes in information communication are yet to come. If computer specialists who are drifting towards information technology are exposed more systematically to the information field, the results are likely to be far more fundamental, effective and speedy. So it would be highly useful, in fact, ideal if some appropriate courses in information are designed for computer specialists. A new kind of information technologist that would emerge would be an invaluable manpower asset. After all, the application of technology to information handling is only a means to an end and not an end itself and the information technologist undergoing the course needs to keep the end very much in view.

Subject specialists working at mission-oriented or problem-oriented information centres capsule information collected from a variety of sources for a specific use. Some have a flair for writing but others need to cultivate such skills. Subject experts without these skills would never perform their tasks well. In fact, reporting original research is far easier than writing a critical review or preparing a digest for decision-making in a short time. Excellent guides, manuals and handbooks exist for technical writing, reporting original research and other types of primary communications. But no such reference material is available to deal with the consolidating and repackaging of information. Neither is a formal training course available. Experts engaged in this work have to design and develop specialised courses, besides producing useful tools.

In western countries, a group of experts often called "gatekeepers", have been identified in research and development institutions and similar bodies. They have an all-round knowledge and expertise, and are active seekers of information whether through formal or informal channels. They are adept at interpreting information, at recognising its significance for their own as well as their colleagues' work and at explaining and demonstrating it to others. There are such all-round seekers of knowledge in India too. They need, however, to be carefully identified and brought into the mainstream of information organisation and service.

Looking ahead

With the information revolution inexorably round the corner, pushing us into the information age, how long will the present information institutions still retain their present form and structure? Futurologists forecast a paperless communication system emerging by the turn of the twenty-first century. It is sure to disembody the library which at present occupies an important place in the total information system. Future librarians or information scientists would be consultants, sitting in their offices, surrounded by computer terminals and other electronic equipment connected to a number of data bases, assisting clients in their pursuit of knowledge and information.

Paper-print based primary publications, however, cannot be very easily replaced and existing institutions servicing them need not be totally displaced either. (Those interested may look up a delightful and witty article "Learn with BOOK"—an acronym for built-in orderly organised knowledge—by R. J. Heathorn in *Punch*, 9 May 1962, which highlights the comparative ease and simplicity with which books pack information for most purposes.) Before very long, however, secondary publications such as indexing, abstracting and other types of bibliographical tools that provide access to the primary publications may not be available in the present printed form. Already about 600 bibliographical computerised data bases are available on-line in Europe and the US providing a variety of bibliographical services. Such data bases are rapidly increasing in almost every subject. We are so much dependent on both primary and secondary STI produced outside the country, that it is high time we determined our future policies, plans and programmes for organising our national information systems.

It is then imperative that a study project for manpower planning be taken up immediately by an appropriate body, possibly by the National Information System for Science and Technology (NISSAT). The study should encompass a wide range: an in-depth assessment of the existing set-up for education and training in library, documentation and information sciences; an estimate of the information manpower force in terms of types, quality and quantity for the next ten years; professional education and training for the operation, supervision, management, design and development of information systems and services; continuing education programmes and workshops for all categories of information personnel; faculty development programmes; good career opportunities to attract talented young persons to the information field; placement programmes for the personnel turned out of the information schools; fundamental and applied research in information science, etc. The aim should be to build up a cadre of information scientists and technologists with diverse specialisations and skills, operating with perfect cohesion to organise and offer high-quality information services.

A viable national information policy will stem not merely from recognising and accepting that information, as a vital key to socio-economic change, is worthy of care, development and management, but only by a commitment to it at the highest levels. A high power national commission comprising a cross-section of experts from various fields, including a few members of Parliament should be set up to study all the problems of information in the country and recommend a suitable course of action for developing a national scientific, technological and societal information system.

T N. RAJAN

Mr. Rajan is the Head of the Training Division of the Indian National Scientific Documentation Centre, New Delhi. He is also a member of the Education and Training Committee of the International Federation of Documentation. He has been with the Vivekananda College, Madras, the Indian National Bibliography, Calcutta, the Library of Congress, Washington DC, USA, and the Library Science Department of the University of Madras

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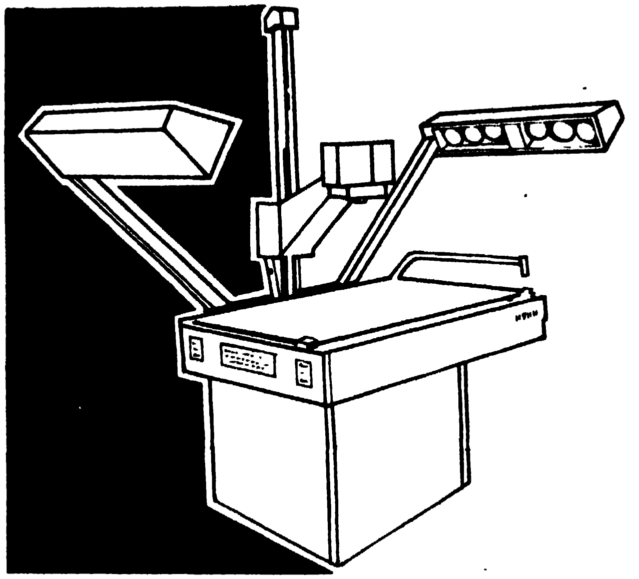

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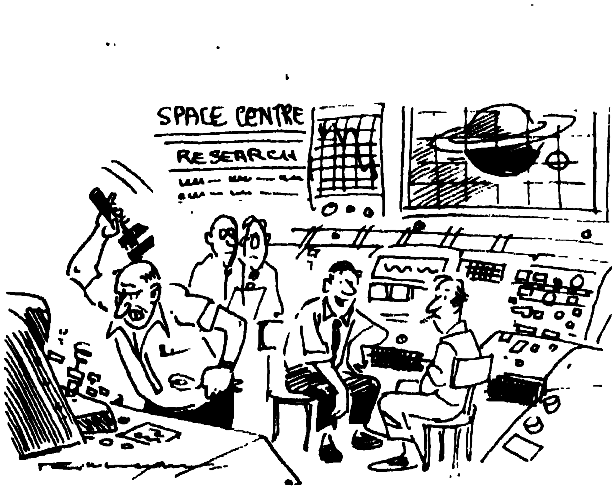
This World of Science!

By R. K. Laxman

"Suddenly I heard a voice shout, "Peeping Tom"—and at the same time something hit my eye!"

"Watch out Doctor, the needle has come out through the other end!"



"He's amazing! He has some unconventional ways of releasing the jammed shutter of our satellite camera millions of kilometres away"

"The construction couldn't stand even one monsoon—evidently, it's adulterated cement!"

...and of Scientists

LORD Rutherford (1871-1937) had an infallible instinct for the essential elements in experiments. His experiments were simple and direct, and often employed apparatus that was primitive even by the standards of his time. One important segment of his beta-ray work reportedly was done mainly with electroscopes made from discarded cigarette tins. His students and colleagues partook of his volcanic energy either naturally or with encouragement. Prof. H. R. Robinson, a former student, has recalled in an obituary published in the *Proceedings of the Physical Society*: "Rutherford's attitude to long hours in the laboratory was charmingly inconsistent. Officially, he was opposed to night work, but he had a habit of leaving the laboratory about seven, and on his arrival next morning at nine asked how the work had gone in the meantime". The emergence from his study of the strains of 'Onward Christian Soldiers' was a sure sign that things were going well!

DESPITE his brilliance as an experimenter, J. J. Thomson had little or no manual dexterity. The actual manipulations required in his experiments were performed by a laboratory technician who soon learned that, at all costs, Thomson must be prevented from touching the apparatus. Otherwise, his awkwardness would inevitably result in some damage to the equipment.

C. UBEROI

THE Swiss zoologist Albert Kolliker, in the 1840s, dissected the modified arm hectocotylus, which is, in fact, the copulatory organ, of the male Argonaut, which he found inside the body of the female. Kolliker found sperm cells typical of cephalopods, and jumped to the conclusion that he had discovered the elusive male Argonaut which, he reasoned, lived as a parasite in the female—which is not the case.

In his eagerness to publish, he "invented" evidence. He went on to make fictitious illustrations of the gills, circulatory system and digestive tract of his so-called male Argonaut. Subsequently, in 1853, when Heinrich Mueller of Germany described the real male, Kolliker realised his error: he sportingly attached a corrigendum to Mueller's paper. To avoid embarrassment, he bought all copies of his earlier, erroneous publication and destroyed them. This rare paper is now a collector's item!

B. F. CHHAPGAR

SCIENCE SHAPES LIFE

PERSECUTED BY DEAFNESS

When one's normal hearing gets dulled, says a report from the US by Stanford University psychologists, paranoia often follows. The persons, unable to catch the entire conversation, often feel that the "whisperers" are either conspiring against them or ridiculing them. As a result they become sad, suspicious and, at times, cantankerous. This problem has been noticed in several old people whose hearing is dimmed.

The Stanford psychologists designed an experiment to verify if there is any link between the handicap and paranoia. They hypnotised a set of healthy students: some of the hypnotised students were told they'd wake up partially deaf and others were hypnotised without any such suggestion. Of the hypnotised hearing impaired group, only some knew that their hearing ability had been impaired. All three sets of students' reactions were then rated by standard personality tests. The hearing impaired group who were unaware of their deafness did show a greater degree of paranoia than the others.

Even in hospitals, it has been found, more deaf people were paranoid than otherwise. Involuntary isolation and numerous misunderstandings arise from the problem. The aging person himself does not realise that his hearing is failing and thus becomes paranoid. His relatives also, not knowing the root of the problem, think that the person is becoming senile.

CANCER REVEALED IN CHROMOSOMES?

For years, scientists have wondered whether cancer cells have normal chromosomes—the rod-shaped bodies rich in nucleic acids, proteins, amongst other chemicals. Recent studies by geneticists at the University of Minnesota, USA, took a hard close look at chromosomes. They found that cancer cells, obtained from patients with leukemia and breast, colon and cervix cancer, all exhibited certain anomalies in chromosome structure. The question whether these abnormalities are common in different people with the same cancer is yet to be answered.

Dr. Jorge Yunis and his colleagues combined the techniques of high-powered microscopy with those of biochemistry to get a better look at the chromosomes. Stained chromosomes with 1000 and even 3000 bands rather than the previous 200 to 300 bands per complete set were obtained. The researchers have even identified 10 genes per band and have come close to pinpointing the groups of genes responsible for particular cancers.

This finding holds out promise for patients suffering from different types of cancers. Besides quick diagnosis and confirmation of cancer, this technique gives an idea about the extent of cancerous damage and the consequent survival period for the patient. Now, hopefully, differences in chromosomal abnormalities will differentiate between a patient who can live for, say, one month or five years and the time of treatment can also be determined accordingly.

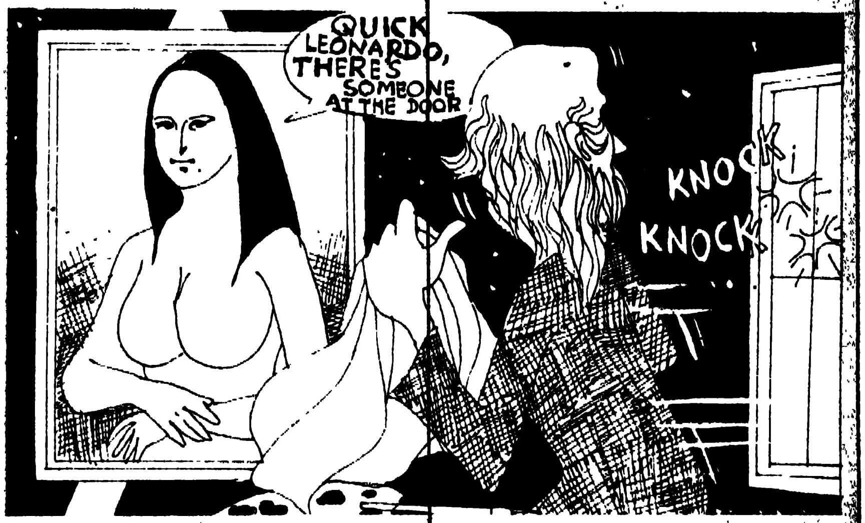
SUGAR COATS TO PROTECT FRUITS

Peter Lowings of the Department of Applied Biology, Cambridge University, UK, has come up with a discovery. He has successfully devised a protective coating for soft fruits like bananas and peaches, to prevent them from ripening fast. The treated fruits acquire a longer shelf-life.

The coating consists of a film of sucrose, esters of fatty acids and some complex sugars. The mixture is sprayed and gradually allowed to dry; an effective barrier is formed which prevents the atmospheric oxygen from entering the fruit, but allows the carbon dioxide produced inside the fruit to escape. Water, in addition to compounds like esters and aldehydes that contribute to flavour, is retained intact within the fruit.

With this new coating, fruits can be transported easily without their getting spoilt. And, above all, you needn't wash them—the sugar coating has no harmful effects.

MONA LISA'S GARB


QUICK LEONARDO, THERE'S SOMEONE AT THE DOOR
KNOCK KNOCK

Mona Lisa has the knack of coming into the news often enough without even batting an eyelid. Not content with admiring the enigmatic portrait, scientists have often come up with fantastic theories and conclusions. Some time back they attributed her flawless complexion to pregnancy. With her enigmatic close-lipped smile, according to one, she was hiding decayed teeth. And there have been other statements about her health or physiological condition we might never be able to verify. Right now US physicist John Armus has another explanation for the mischief in that smile—Mona Lisa, it seems had no clothes on.

And can we be sure this time? No, the Louvre will naturally not allow such tampering. But Armus won't give up. He plans to use NASA's computer enhancement technique, which touched up photos of Jupiter and Saturn, for the painting. By subtracting the yellowish tinge which the varnish acquires on aging, he has managed to simulate the portrait as it looked when just completed. In his "just finished" portrait, Mona Lisa acquires an alabaster complexion. Armus got his idea from art historian Carlo Pedretti, University of California, Los Angeles, who thinks the dress was painted on later because Leonardo da Vinci's other paintings around that time all had nudes and partially dressed women.

By extending the computer technique Armus hopes to identify areas of unusual pigments which might indicate that the gown was painted on after the portrait was completed. How far the computer *vastraharan* will succeed we have yet to see. And if the garb was painted on, there is another teaser: was it at the instance of Francesco del Giaconda, her husband?

A ROSE OF ANOTHER AGE

If you've ever wondered what the rose ancestor looked like, you now have a clue. Swedish scientists sifting through sediments have found an intact rose which bloomed in the late cretaceous period when the last of the dinosaurs, large flying reptiles and marine reptiles were around. It is rare to find an entire fossil flower and scientists have had to make do with imprints or fossils of fruit and pollen. This 80-million-year-old blossom which has been miraculously preserved looked like a bit of charcoal to the naked eye. When put under the electron microscope, however, it looked like this

WOMEN COPE BETTER WITH WIDOWHOOD

Widows usually outnumber widowers mainly because women generally outlive men and thus there are fewer widowers to begin with. But there seems be one other reason too. K. J Helsing, M. Szklo and G. W. Comstock, Johns Hopkins University, Baltimore, USA, have found that widowers died sooner than married men of the same age and circumstances; widows, however, did not differ from married women. Why this is so is yet to be studied.

The researchers waded through 12 years of census records and studied 4,000 widowed persons aged 18 or more. They included such factors as smoking history and number of housemates, which would affect mortality. And strange as it may seem, though widowers died sooner, they died of the same natural causes and diseases as their non-bereaved counterparts. This probably indicates how much difference marriage makes for a man's health! The same, however, cannot be said of women—marriage seems to make little difference.

This is underlined by the fact that the death of widowers occurs several years after bereavement and so trauma can be ruled out. Remarried widowers,on the other hand, had a lower mortality rate than even the control group!

MORE PROBLEMS FOR DIABETICS

Now there is one more problem for the diabetics. Surviving with the metabolic disorder, diabetes (where the insulin production is affected and consequent defect in carbohydrate metabolism), entails difficulties such as delayed wound healing and proneness to cardiovascular diseases.

Latest research findings at the Edinburgh Royal Infirmary's diabetic and dietetic department reveals that the various intrauterine devices (IUDs) such as loops, T-coils and shields, whether made of copper or plastic, are ineffective in diabetic women. One clinic reported that nearly one-third of the diabetic IUD users become pregnant within one year. As early as 1974, a Danish group had published similar results.

These results are indeed disturbing, as the IUD had always been considered the best form of contraception for diabetic women. The pills have their own limitations, more so in diabetics, where the risk of cardiovascular diseases is high.

What are the reasons for the high rate of failure of IUDs in diabetics? It seems the reason lies in the biochemistry of the blood proteins. Fibrin, a protein, requisite for blood clotting, is also necessary in the uterus for the successful implantation of the fertilised ovum. In normal women, the IUDs seem to accelerate the breakdown of fibrin, while in diabetics this breakdown is retarded. This ensures adequate amounts of fibrin for implantation and thus leads to failure of IUDs.

DIAMONDS IN THE SKY

Where does one look for diamonds? Right in the cores of Uranus and Neptune, the gassy planets in the outer solar system which are nearly three times as massive as Earth. Both planets have abundant sources of carbon, of which ~~diamond~~ is ~~but one form;~~ the carbon comes from the dissociation of methane under high temperatures and pressures.

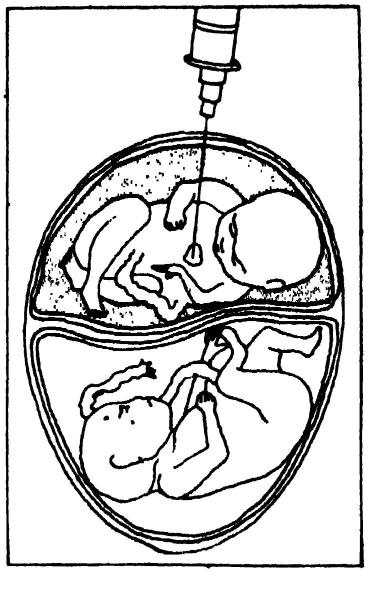
Marvin Ross and his colleague F. H. Ree of the Lawrence Livermore National Laboratory, California, USA, calculated the equilibrium between methane, carbon and hydrogen under the temperature and pressure conditions existing in the planets. Both the planets are believed to have a rocky core topped by a thick layer of water, liquid ammonia and methane which is curiously known as the ice layer. Both planets have an atmosphere consisting mainly of hydrogen and helium.

The ice layer is subjected to intense pressure and temperature. The pressure increases from 200,000 atmospheres at the top of the ice layer to around six million atmospheres at the rocky core: the temperature increases similarly from 2200°K to 7000°K. Water and liquid ammonia can be compressed but methane dissociates under these conditions.and the carbon settles on the rocky core, probably as diamonds, say the scientists. The diamond layer would constitute about 17 per cent of the planetary mass! Under the extreme temperature and pressure at the inner portion of the ice, the diamond layer would probably metamorphose into metallic carbon, a form that has not been seen on Earth

SELECTIVE ABORTION

When a pregnant woman has more than one fetus and one is defective, it can be selectively aborted. The first time the technique had been successfully carried out is in Sweden. The second case has just been carried out in the US. The case relates to a 40-year-old woman 17 weeks pregnant. Amniocentesis showed that she was carrying twins and the fetus located on top was abnormal.

Weighing the pros and cons, the woman opted for aborting the defective fetus. The point in favour of the decision was a fair chance of success of the medical intervention and not having to raise a mentally subnormal baby. The disadvantages? The wrong fetus or both fetuses could be destroyed and a probability of the premature delivery of the surviving fetus.



Locating the fetuses by ultrasound on a television screen, obstetrician Thomas Kerenyi and his team at the Mt. Sinai School of Medicine, New York City, inserted a needle into the heart of the affected fetus and drew out nearly 50 per cent of the total blood volume. The heartbeat ground slowly to a halt. The blood sample analysis showed that it was indeed the abnormal baby that was destroyed; the normal baby weighing 3.2 kg was born at full term along with the destroyed fetus weighing around 60 g.

THERE'S CANCER ON THE ROAD...

Women living along streets with heavy traffic (a minimum of more than 15,000 vehicles a day) are twice as prone to cancer of the lung than women living along less busy roads; men aren't similarly affected. These are the findings of a paper by Lincoln Polissar and Homer Warner at the Fred Hutchinson Cancer Research Center, Seattle, USA.

Lung cancer was selected because it could be linked with inhalation of auto-exhaust fumes. Despite matching age, socio-economic conditions and geographic district, the study did not take into account factors like smoking which are strongly linked to lung cancer.

Using the local tumour registry, the researchers used three analyses to locate patients and correlate them with traffic density. However, the study started out to verify an earlier finding by Swiss scientist Max Blumer, which, it found was *not* statistically significant. Blumer had found that the risk increases by a factor of 9.0 for all types of cancers. Polissar explains the discrepancy as due to differences in the two studies. "Blumer found an elevated risk for all cancers; we studied only lung cancer... Blumer's retrospective cohort study followed people forward in time, while we imprinted the level of past exposure from the traffic volume of the current address."

...AND IN DAD'S OFFICE

How can your work harm your child? Children whose dads (or moms) work in certain industries are more prone to brain tumours. Scientists at the University of Southern California School of Medicine, USA, found that if parents worked with chemicals, their children were thrice as likely to have brain tumours.

Ninety-two children with brain tumours and an equal number of matched controls were studied. All children were younger than 10 years. Children of fathers exposed to paints ran a risk seven times greater. Thirteen per cent of the fathers with affected children worked in the aircraft industry; only two per cent of the fathers of healthy children were in the aircraft industry.

The researchers cannot pinpoint the causative factor(s) but it is probable that the carcinogens hitch hike on the work clothes. Incidentally men in the aircraft industry also run a higher risk of developing brain tumours—the most common cancer after leukemia.

WATER IS THE BEST THIRST-AID

If it is for quenching thirst, plain water would be your best choice—not a bottled drink. Thirst is a sign that the body is dehydrated and the excess electrolytes in a bottled drink delay the hydration process.

Most soft drinks marketed in the US, according to a report in *Sportsmedicine Digest*, are hypertonic—they contain higher concentration of the electrolytes sodium and potassium, than the body fluids. As a result, when ingested, they tend to draw out body fluids into the stomach. This is the body's mechanism for diluting the excess electrolytes; only after dilution can the beverage be absorbed. In the case of water there would be no such diversion in the path of absorption. Patrica Beckwith of Children's Hospital, Los Angeles, USA who made the survey of the several marketed soft drinks recommends diluting the drink, especially after strenous sports. If you must have soft drink, dilute it.

But does not the body lose electrolytes during heavy sweating? Yes, it does. And need the salts not be replenished immediately and should not the soft drinks help? Not if you've had a normal meal before the strenuous activity.

AIRCRAFT MAKE RAIN

Aircraft pollution has a positive side too, says the Head of the Atmospheric Sciences Division of the Illinois Water Survey Department. It seems the areas around Chicago, USA, are always cloudy and grey, presumably because of the exhaust fumes of the overflying jets using the world's busiest airport—O'Hare airport.

The weather experts say that this makes the days in the highly polluted areas cooler and more rainy. The same, however, cannot be said of the areas lying outside the flight paths. But that's not all. The cloud cover traps heat at night making the nights and winters sultry and warm. Evaporation from the ground is considerably reduced, providing a rich source of moisture to the plants. Naturally, farmers view this with great joy—the aircraft now give them rain and ample moisture to grow their crops.

INSECT EXCHANGE

When a group of scientists from the US Department of Agriculture went to China, they carried with them a strange gift—wasps. And on their return they were given green lacewings, predatory mites and parasitic wasps.

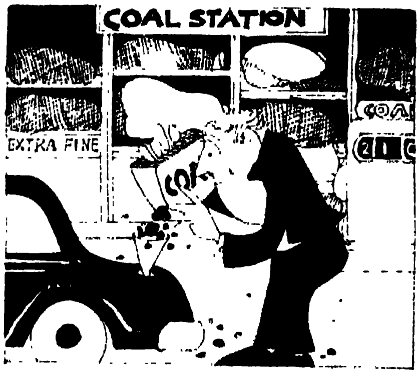
In the early days explorers nearly always took home with them the exotic and strange species of animals and plants they came across. But the current Sino-American barter is not for such curious mementos. The US has many agricultural insect pests that are not native; in their new environment the insects lack their natural enemies, and as a result thrive and become a menace, says Joan Wallace of the US Department of Agriculture. The gifts from China are expected to control cotton and tobacco pests, mites that harm vegetables and citrus fruits, parasite gypsy moths and other forest pests. The American wasps in China are expected in return to be used to control aphids and caterpillars there.

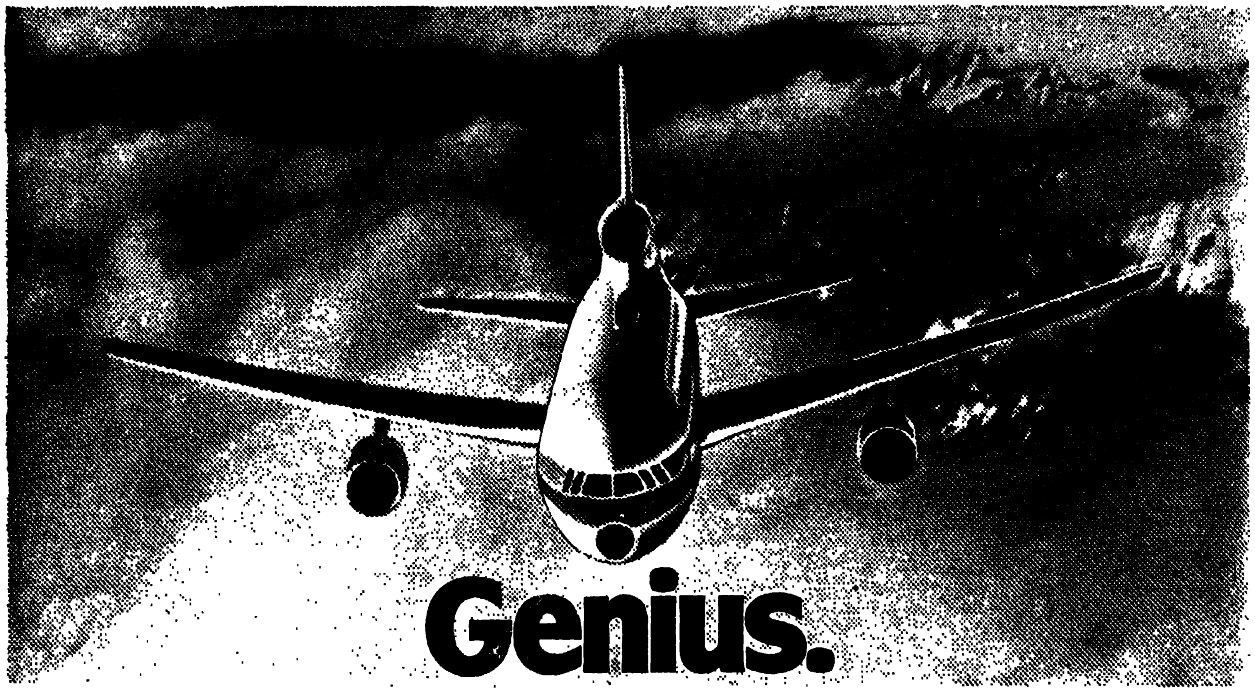
The insects from China are now being sent to universities for testing under quarantine conditions before field experiments lest there be some unforeseen factors and the whole project misfires.

COAL-DRIVEN AUTOMOBILE

A new technique that has made it possible to grind coal into extremely fine powder will pave the way for the coal-driven car. The ultrafine powder, carried from the automobile's storage tank to the engine by a stream of compressed air, burns very well.

General Motors, USA, has developed two prototype models of the coal car. However, further modifications are required for the engine before the car can be put on the road. When the powdered fuel production goes on to a commercial scale, it is expected to cost 0.6 times the cost of crude oil production. Coal refining and powdering for automobile fuel will probably help to solve the energy problems of many countries. Coal is more plentiful than oil, and cheaper too. Even fares may come down!





The L-1011-500's technology sets it apart from other aircraft and makes it the long-range jetliner of the Eighties.

You're looking at the long-range member of the Lockheed's family of L-1011 TriStars. It brings airlines a combination of exclusive features that give the L-1011 a level of technological genius.

Those features make the L-1011-500 uniquely qualified to serve airlines profitably on one of the fastest growing sectors of passenger travel – long; moderately traveled routes of more than 3000 miles.

Look at the long, graceful wings in the picture above. They've been lengthened nine feet since the L-1011 first went into service. This reduces drag and saves impressive amounts of fuel. It also produces the smoothest flight in the skies. Only the L-1011 has been able to lengthen its wings to help offset the soaring price of fuel. An exclusive system of computer-driven Active Controls made this possible. They adjust wing ailerons automatically to reduce aerodynamic loads on the L-1011-500's wings. The L-1011 is the only aircraft operating with Active Controls.

Another fuel-saving exclusive.

An exclusive Flight Management System automatically selects the best speed and power levels, and then controls throttles in flight to save even more fuel.

Another exclusive system – Direct Lift Control – gives the pilot more control at all times on the glide path as the L-1011 approaches the runway. This smooths out the ups-and-downs experienced on other jetliners.

Then there's the exclusive Flying Tail. It's the only one found on big jetliners. The entire horizontal stabilizer moves at the pilot's command instead of flaps at the rear of it. This gives the pilot more control at all times.

Technology cuts maintenance costs.

Lockheed has not neglected the critical area of maintenance costs. A new digital autopilot has entered service recently on two L-1011 airlines. Smaller, lighter, and without moving parts, it's 150% more reliable than current systems. The L-1011 is the first big jetliner to introduce such a maintenance-saving system.

Another L-1011 system is found on few other aircraft. It's a system that enables the L-1011 to land routinely at some airports in bad weather that turns other jetliners away. This not only is another fuel saver, it spares passengers the inconvenience of being diverted to other airports.

The L-1011 keeps getting better.

Most of these systems have been added to the L-1011 since it first flew. In fact, the L-1011 is proving to be remarkably able to accept new technology that helps keep it the most modern jetliner in the skies.

In a sense, the L-1011-500 has yet another exclusive. It is the smallest of the big, wide-cabin, three-engine jetliners. That small size, coupled with the L-1011-500's array of technological exclusives, helps give it an unmatched combination of low plane mile and seat mile costs. And that translates into superior profitability on long, moderately traveled routes. The new two-engine jetliners being developed are not L-1011-500 competitors. They lack the range for long routes; nor can they be certificated to carry passengers over long stretches of ocean. That requires three engines. The big four-engine jetliners have much higher acquisition and operating costs than the L-1011-500 for long, moderately traveled routes.

Open skies and other changes.

More and more, agreements among nations are resulting in "open skies" that permit airlines to pioneer new routes. More and more, passengers want to fly direct instead of spending time in airports waiting for connecting flights. In short, the times have changed radically, and the L-1011-500, with its superior technology and unequalled combination of low plane mile and seat mile costs, gives airlines a competitive advantage. It's a flexible jetliner.

By 1985, 32% of the routes will be long and moderately traveled. That figure was only 25% in 1975. If you're interested in developing new routes in a changing, competitive environment, hadn't you better get interested in the L-1011-500?

Lockheed L-1011 TriStar

Tuning our body clock

M. K. Chandrashekaran

The desynchronised biological clock may be the cause of stress and depression

IN each one of us—and also in other animals—there is a timing device which regulates our daily activity to synchronise more or less with the 24-hour geophysical day. These biological rhythms, known popularly as biological clocks, may consist of over a hundred different functions. Some of these rhythms are upset easily while some—like the potassium levels in blood—are more tenacious.

Like man-made clocks, our biological clocks may also run faster or slower than normal and when this happens the person is likely to feel under the weather. What keeps our biological clock attuned are environmental and social cues.

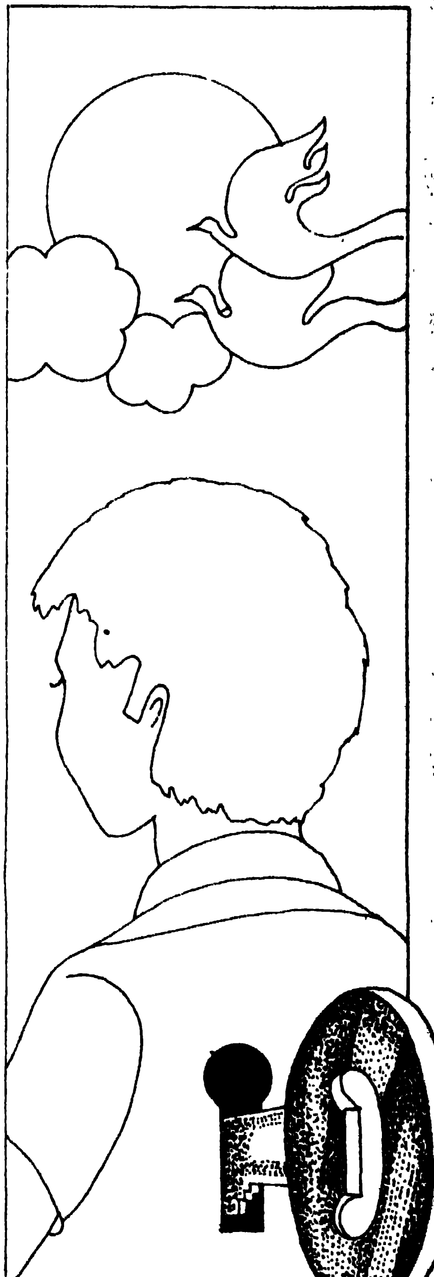
In the sixties a young spleologist was interred in an ice cave in the French Alps for 63 days without any clues as to what was happening in the outside world. He kept a record of his sleep-wakefulness cycle, counted the days and reported on his general well-being. At the end of the experiment he had mentally lost 25 days. Without his knowledge, his biological clock which had a "free run" had clocked an average day of 24 hours 31 minutes. Only once during this entire period did his biological clock synchronise with the outside world and an examination of his record later showed that this was the only day he had reported feeling fine. When allowed to run free, our biological clocks usually run slower; there are instances, however, when they do speed up. A physician experimenting on his flu-affected wife found that her time flew faster the higher her fever rose. One explanation is that at higher temperatures our body processes speed up and therefore probably our biological clock speeds up.

Since our biological clocks can go awry it is necessary to know how desynchronisation affects us and how we keep our body clocks properly tuned. Biological clocks have been intensively studied for the past two decades in the US, Europe and Japan.

C. W. Hufeland wrote in 1797, "That period of 24 hours, formed by the regular revolution of our Earth, in which all its inhabitants partake, is particularly distinguished in the physical economy of man.... It is, as it were, the unity of our natural chronology." The regular revolution of the Earth, alluded to by Hufeland, generates the 24-hour calendar day. Sunrise and sunset form the most universal, reliable and noise-free time cues or *Zeitgebers* (German for time givers) for the biological clocks. In fact light/darkness (LD) cycles, both in nature and in the laboratory, are such major entraining agents (or timers) that only two biological rhythms—that of a leaf-cutter bee of South America and of humans—have ever been reported to defy entrainment. Both cases may, however, need some up-dating if not complete revision.

Cues that tune biological clocks may be strong or weak or subtle. Light and darkness, as mentioned, are strong. Temperature cycles are also known to synchronise biological clocks effectively.

Weak cues may be "social" in origin for some higher animals and man, or they may be availability of food and water—they are for the common Indian squirrel, food cycles and for the squirrel monkey, both food and water. The much disputed subtle cues find a staunch supporter and champion in F. A. Brown, Jr, formerly Morrison Professor of Biology, North-Western University, Illinois, USA. For well over 100 years now, the subtle cues, variously ascribed to an 'X' factor in the environment, cosmic ray showers, electrostatic and magnetostatic field variations attending the rotation of the Earth, etc, have been invoked to account for the biological rhythms that persisted under constant conditions in the laboratory and in caves. Magnetic fields appear to be 'in' now with the recent findings of W. Wiltschko and R. Wiltschko of the University of Frankfurt, FRG, of magne-



tic compass orientation in pigeons. Interestingly, as demonstrated by K. Schmidt-Koenig, presently at the University of Tuebingen, FRG, pigeons possess precise biological clocks.

The subtle cues supporters, chiefly Prof. Brown, also often subscribe to an exogenous nature for biological timing, making the expression 'biological clocks' thereby anachronistic. However, a vast body of evidence has accumulated implicating the endogenous, heritable and genetic nature of the biological clock. Whether the subtle cues have a *Zeitgeber*—synchroniser—status is controversial. Controversy apart, let us see how biological clocks in animals and man are tuned by demonstrably social factors.

Tuned and free-running clocks

Most biological rhythms are in a state of strict entrainment by sunrise/sunset to the 24-hour geophysical day. They are tuned daily (Fig. 1). When animals, plants and humans are removed into apparent-time-cueless conditions as in a cave, bunker or laboratory, the rhythms free-run resorting to an inherited *Eigenfrequenz* (German for innate frequency) which is always a little shorter or longer than 24 hours (Fig. 2). Free run vouches for the endogenous nature of the rhythm. It is the antithesis of tuning or entrainment.

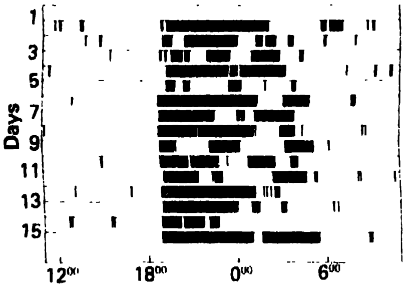


Fig. 1

Entrained state of the biological rhythm in the flight activity of a microchiropteran male bat under natural light/darkness conditions. The recording was done in the laboratory. The vertical markings denote flight, intense activity cause bands and rest is indicated by horizontal tracings

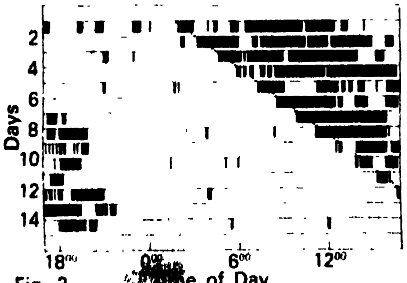


Fig. 2

Free-running state of the flight activity rhythm of a microchiropteran male bat when recorded under continuous dim light of 5 lux in the laboratory. The period is longer than 24 hours

Nathaniel Kleitman formerly of the University of Chicago, a pioneer on sleep/wakefulness activity in humans and Bruce Richardson shut themselves up in a chamber of the mammoth cave in Kentucky, USA, in 1938. They wanted to see if they could adjust their clock to any period other than 24 hours. They spent 32 days in the cave living in a self-created 28-hour cycle of 19 hours activity and 9 hours rest. They wanted to see if they could stretch the clock beyond *Eigenfrequenz*. Richardson (23 years old) could reset his clock but Kleitman (43) could not adjust to this regimen. Richardson's biological clock inside the mammoth cave is the first scientific record of a 'free-run' in humans in the modern research tradition.

Social synchronisation

When certain precision and predictability in the activity of organisms are observed to coincide with similar temporal features of an environmental factor we talk of possible entrainment. In the case of animal populations, the question of 'social interactions' arises. Individual behaviour may be 'triggered'. However, the mutual synchronisation of the rest of the clocks of a population might follow a social basis if only the 'leader' or 'alpha' animals are activated. It is a common observation that most birds and social mammals leave and return to their roosting sites *en masse*. This "emergence by coup" is definitely a socially synchronised event which is meant to confuse predators.

In 1966 one of the early studies attempting to socially entrain (tune) the biological clock in the common sparrow, *Passer domesticus*, made use of the songs of conspecifics. The locomotor rhythm of the sparrow was successfully driven by playing back the bird song for four-and-a-half hours each day. Similar results came in for two other species of birds the same year and the findings generated much scientific enthusiasm since it all appeared to be in the fitness of things. However, a year later it was found, somewhat unromantically, that cycles of mechanical noise administered by a loud buzzer entrained activity rhythms of three species of passerine birds!

Activity rhythms of some mammals have been shown to be influenced by other members of the species. Red wolf-coyote hybrids, it has been found, mutually synchronise their activity rhythms. Two packs of red wolf-coyote hybrids consisting of three males and two females each were studied first in separate enclosures and then together. When united, their activity rhythms which were different, tended to synchronise. The periodic bouts of howling the animals indulge in during maximum activity might have acted as a synchroniser.

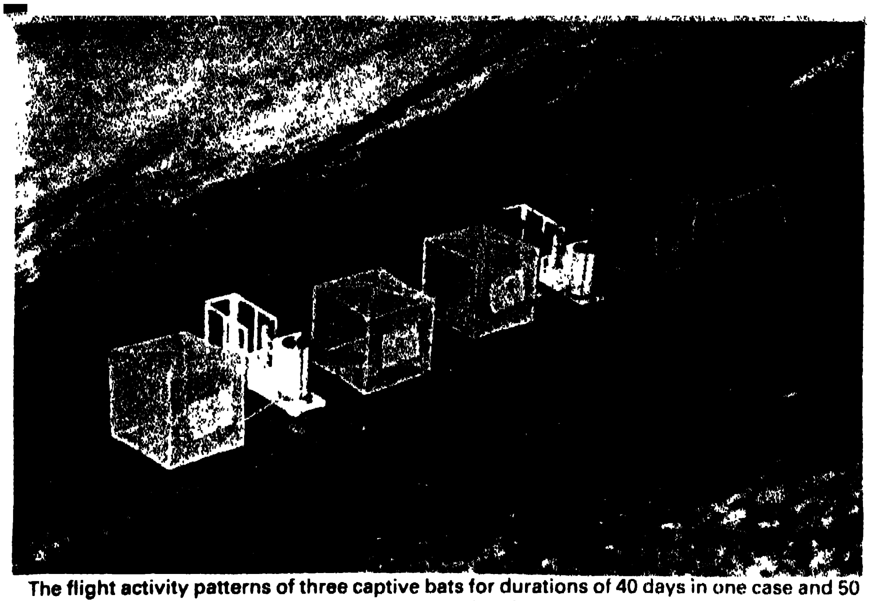
Studies on the influence of social history and crowding on the activity patterns of domesticated strains of mice *(Mus musculus)* and brown rats *(Rattus norvegicus)* reveal that crowding produced a shift in the rhythm of activity from primary nocturnality to primary diurnality, especially among males. But normality of the rhythm of activity is maintained only by two completely divergent types of animals: first, the socially most dominant individuals and second, those individuals whose behavioural and perceptual maturation is so poor that they behave as if they are mostly unaware of the presence of associates. Domestication in animals may in itself bring about behavioural abnormalities, such as the second category. (It is doubtful if animals would ever be behaviourally so degenerate as to be "mostly unaware of the presence of associates" in nature, and if they were, whether these individuals would not be eliminated by selection pressure.)

In deer mice, activity and even metabolic and feeding rhythms show modifications which are traceable to social interactions occurring within the hierarchical structure of the habitat. Isolated dominant males and habitat dominant males had significantly higher mean daily oxygen consumption than either isolated or habitat intermediates or subordinates. All ranks showed synchrony with LD cycles.

Synchronisation by ultrasonics

Laboratory studies have their limitations, especially when they pertain to behaviour. Field ethological studies on the behaviour and biological clocks of microchiropteran bats have been carried out in Madurai inside natural caves.

A colony of about 400 to 500 insectivorous bats of the species *Hipposideros specoris* inhabit a 'true cave' (that is, a cave with just one opening) close to the Madurai University campus. The cave has several labyrinthine ramifications 15 to 50 m deep, that is, from its mouth. The bats use several of these pockets as their daytime roosting place. Most roosting spots show great constancy of temperature (27°C) and humidity (95 per cent) and the darkness is absolute, day and night. Within the cave, there is hardly any clue to the



The flight activity patterns of three captive bats for durations of 40 days in one case and 50 days in the other two cases recorded 40 metres inside a narrow 'true cave' The bats could fly within the flight activity cages and the movements of the cages were directly recorded. Activity bouts are indicated by vertical patches and the horizontal lines indicate rest. The activity/rest data are schematised from original data and presented one below the other for successive days

passing of time. Yet foraging flight occurs regularly 10 to 15 minutes after sunset. It is clear that the animals are aware of the sunset.

The sequence of events culminating in such regular outflights are as follows. The bats awaken well before sunset. They then stretch, preen themselves and undertake short flights within the dark recesses. They fly into an outer chamber that opens to the world outside through a small window-like mouth; in this chamber they "sample light". When it gets sufficiently dark outside they fly out.

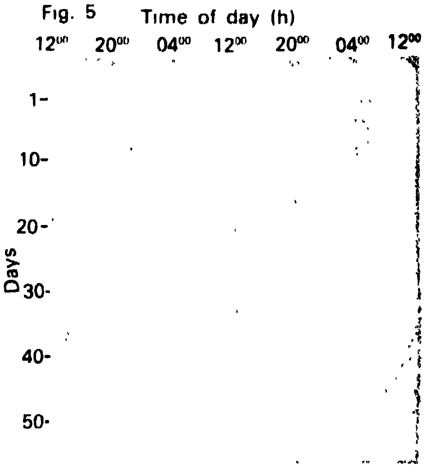
The first question that arose was: should each bat sample light for itself or would conspecifics relay the information to those in the interior region? The only way to find this out was to keep a few bats prisoners in their own cave 40 m deep and record their flight activity. Flight cages with writing stylets and mechanically wound thermohygrograph drums were used in the study (Fig. 3). The activity data of the experiment which lasted 50 days (the blotches in Fig 4) show that even the captive bats recognised the time. That means the free-flying conspecifics apparently transmit the news of the sunset.

A second experiment further probed the hypothesis of social biological rhythms synchronisation in this bat If free-flying members of the bat colony transmitted the message of time, shouldn't a solitary bat in a solitary cave be helpless? The solitary bat is indeed helpless as regards time (Fig. 5). Its rhythm "free-runs" and gains about 20 minutes every day.

The following factors might mediate in the synchronising process: (1) flight noise of free-flying members, (2) some unknown pheromonal or chemical message emitted by the flying bats, and (3) ultrasound that these bats emit.

The first two factors are present continuously inside the caves; however, they could steeply intensify. While not ruling this out completely we find the ultrasonics factor as the most interesting *Zeitgeber*.

This bat is silent to humans. Ultrasound has been demonstrably used by bats only to catch prey, avoid obstacles and in such other immediate behavioural contexts (SCIENCE TODAY, November 1980, p. 36). If we can establish the *Zeitgeber* role of ultrasonics in bats we would be giving it a new and social dimension. Experiments to unravel the phenomenon (with tape-recorded ultrasound, sound-proof experimental cubicles, etc) are underway in Madurai.



A double plot of activity/rest pattern of a solitary male *Hipposideros speoris* bat recorded in a cave without any conspecifics over a period of 50 days Black dots indicate feeding time. The details are schematised from original felt pen tracings. Other details as in the previous figure

Social cues and human clocks

The experiments of E. Poeppel (1968) are to the point. When humans are kept in isolation in a bunker and denied knowledge of all time cues, their circadian rhythm in body temperature runs slower losing about one hour for every 24 hours. Their day thus tends to be 25 hours long (τ = 25 h) (Fig. 6). There are, however, interindividual variations in τ, which decreases if several human subjects are allowed to stay in the bunker.

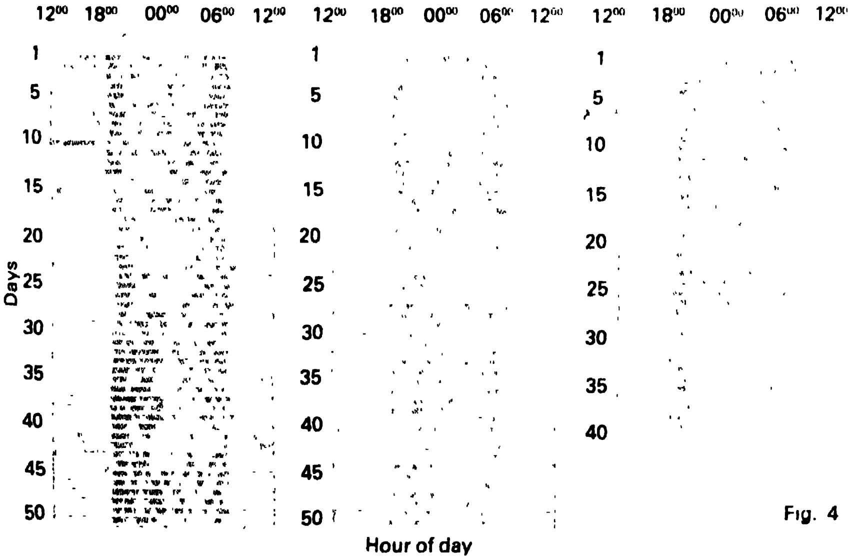


Fig. 4

The flight activity cages and mechanically wound thermohygrograph drums used in recording the flight activity of captive bats 40 m deep in a true cave in Madurai

They then usually show the same circadian period which, nevertheless, is greater than 24 hours. Interestingly a 'compromise' on period length appears to be easier with two subjects ,than with four.

R. Wever working in the bunker of the Max-Planck-Institut at Erling, FRG, found that LD cycles did not entrain any of the several circadian rhythms demonstrated in human subjects. The studies were carried out in hermetic isolation using eight human subjects. In contrast to this finding, 16 subjects living under the influence of LD cycles with supplementary sounds of a gong offered at regular intervals synchronised their circadian rhythms to the LD cycles (Fig. 7). Apparently artificial LD cycles are a very weak *Zeitgeber* but become effective when complemented by regular acoustic signals. Wever concluded that the subjects perceived the gong beats as "social contacts" and that in man "social" *Zeitgebers* are more effective than "physical" synchronisers.

J. Aschoff and his colleagues performed another experiment in the same bunker to further investigate the question of entrainment by means of social cues. Three groups of two subjects each were kept in underground chambers, first for four days, in complete darkness. They lived on a rigorous time schedule. The rhythms measured in physiological and psychological functions at three-hour intervals looked alike in the results obtained from the two segments of the experiment. Social cues, knowledge of time of day and living routine might have entrained the circadian rhythms of the subjects to a strict 24-hour societal day. The social cues apparently were sufficient to entrain human circadian rhythms and the absence of light did not change the mean phase and range of the socially entrained circadian system during four days.

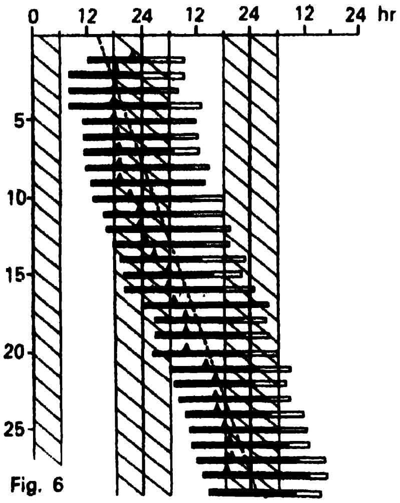


Fig. 6

Circadian rhythm in a human subject under light/darkness cycles. Activity is represented by horizontal filled bars and rest by unfilled bars and maximum of body temperature by triangles. Data over several days are shown in downward succession

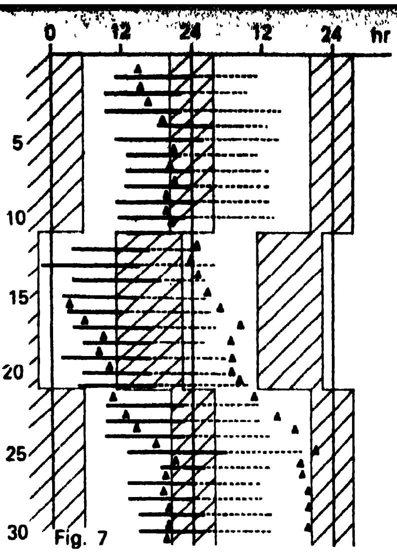


Fig. 7

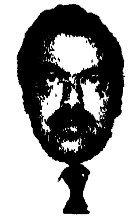
Circadian rhythm in a human subject under light/darkness cycles supplemented with gong beats at frequent intervals. The *Zeitgeber*, LD and gong beats were abruptly shifted (advanced and delayed) twice (days 11 and 21)

Recent studies on adjusting to time zone changes in humans indicate that less disorientation takes place when subjects travel in groups and participate in testing programmes in a group setting. Social psychologists have pointed out that the individual shows increased motivation when performance tests are taken in groups rather than in isolation, and in general social influences seem important in adjusting to circadian rhythms.

Deviations of the circadian rhythms in individuals interestingly appear to lead to symptoms of stress and distress. In a psychologically normal man who suffered from a severe cyclic sleep-wake disorder, investigations showed circadian rhythms in body temperature, alertness, performance, cortisol secretion and urinary electrolyte excretion were desynchronised from the 24-hour societal schedule. The rhythms all had periods which were indistinguishable from the period of the lunar day (24.9h).

W. Engelmann who first discovered that lithium salts slowed down the clock of a flower petal rhythm and the clock in the locomotary activity of a desert rodent has an important and interesting hypothesis. He argues that lithium chloride (LiCl) when administered to endogenous depressives cures them in a matter of a few days to a week possibly by working on their biological clock. The endogenous depressive has a shorter period length of his rhythm than the geophysical day. In other words his clock runs fast. The malady is cured after a week or more of LiCl administration since the clock would have slowed down in the meantime and 're-entrained' to the strict 24-hour periodicity of the societal day. Likewise, "sleep deprivation" for one, two, three or more nights abruptly cured endogenous depressive. It is reasoned that the sleep-deprivation situation might act on the circadian rhythm of humans much as 'inversion' of LD cycles worked on circadian rhythms in general. A 180° shift of LD cycles or their inversion generally 'resets' the rhythm entirely, creating a new phase angle property rather abruptly. Thus there are reasons to believe that period lengths of the circadian rhythm both shorter and longer than the exact 24 hours of the societal environment might lead to physical and psychical disorders in humans.

So far, little information is indeed available on social cues as synchronising agents. In the entire body of literature on sociobiology proper emphasis has not been focussed on such interactions playing the role of synchronising agents to temporal sequences of behaviour. And where social cues and biological rhythms have been considered, the situation has been on a rather stimulus-response level. More studies are needed to establish features and the nature of social synchronisation of circadian rhythms. A new discipline of social chronobiology appears to be emerging, which must be of immediate interest to medical doctors, psychiatrists, ethologists and social scientists.



Prof. Chandrashekaran took his Ph D degree in 1964. In the course of his work, he quite accidentally discovered "tidal rhythms" in an intertidal crab and became a chronobiologist. He worked in the laboratory of the doyen of rhythm research, Professor E. Buenning at the University of Tuebingen, FRG, for eight years successively as German Academic Exchange Service scholar, Alexander von Humboldt Fellow and Research Associate of the German Research Council (DFG). He was Miller Invitation Fellow at Berkeley University of California for two years and received the Shanti Swarup Bhatnagar Award in Biology for 1979. He was nominated to the Board of Directors, International Society of Chronobiology (USA) and elected Member of Guha Research Conference in 1981. He is currently with Madurai Kamaraj University, Tamil Nadu.

ROUND-UP OF RESEARCH

Natural toxins in human foods

FOOD is a complex mixture of thousands of different types of chemicals. It also contains a large number of mostly uncharacterised and apparently harmless chemicals of no known value for human nutrition. But since some of the human diseases of unknown origin are in part due to chemical exposures, food should be investigated.

In fact, a number of natural components of plant foods are known to have induced toxic manifestations in humans or animals These include cancer inducing cycasin in cycad gymnosperms which is used as a source of starch in Japan, pyrolizidine alkaloids, bracken fern toxins, safrole, tannins, besides goitrogens in cabbage, haemagglutinins in beans, oxalates in spinach, and pressor amines in bananas.

Dr. Wayne Ivie and his colleagues of the U S Department of Agriculture in Texas (*Science*, **213** 909) have analysed a commonly used vegetable in USA called parsnip (*Pastinaca sativa*) for its chemical constituents. Parsnip roots obtained from local supermarkets were found to contain three furocoumarins, namely psoralen, xanthotoxin and bergapten with a cumulative concentration of 40 parts per million (PPM) Further, levels of none of the three compounds were affected by washing and cooking of the vegetable, but peeling the root did result in about 30 per cent reduction of the psoralens. In contrast, carrot (*Daucus carota*), another vegetable related to parsnip, which is extensively consumed in India, showed little amounts of the compounds.

Psoralens are biologically active compounds. In presence of light, they induce formation of brown and black pigments (melanisation) in the human skin and are used in the treatment of skin depigmentation. They are also potent photosensitisers and are known to cause mutations in presence of ultraviolet light. Also, these compounds under certain conditions are known to be photocarcinogenic in laboratory animals. The authors conclude that because of these known toxic, photoactive mutagenic and carcinogenic properties of psoralens, parsnip and other psoralen-containing plants may present some toxicological risk to man. They, however, also advocate epidemiological studies and measurement of psoralens in the food.

Similar to these observations, a number of flavonoid compounds which occur in a wide variety of plant foods have also been shown to be mutagenic. Finally, cooking of food at high temperatures has also been shown to produce mutagenic substances. However, the presence of a toxicant or a mutagen in food does not necessarily imply that a hazard is imminent.

It has been said that no human activity is devoid of an element of risk. Are we paying the price of accepting to eat?

P. S. CHAUHAN

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Contraceptives and heart attacks

CONTRACEPTIVE pills form an important part of the fertility control programme in all communities. There have been several reports about the various adverse effects of the long-term use of pills on human physiology. The use of these pills is associated with increased incidence of heart disease, paralytic strokes, high blood pressure, diabetes and increased clotting tendency of blood.

As far as heart attacks are concerned, the natural protection enjoyed by women during their child-bearing age seems to be disturbed by the use of contraceptive pills over a prolonged period. It remains to be seen whether this risk persists after discontinuation of the use of pills and to what extent.

In a cleverly planned and well controlled hospital-based study, Dr. Dennis Slone and associates analysed the influence of pills on the incidence of myocardial infarction (heart attacks). (*New England Journal of Medicine*, **305** 420). Five hundred and sixty-six women between the ages of 25 and 49 years suffering from myocardial infarction were involved 2,000 age-matched patients admitted for various disorders not related to heart disease served as controls.

The conclusions were revealing and could be summarised as follows: 1) women who were using oral contraceptive pills were three to four times more susceptible to heart attacks as compared to controls; 2) the incidence of heart attacks increased with the duration of the use of pills; 3) even in women who had discontinued the use of pills as long as five to ten years prior to the study, the increased incidence of heart attack was evident.

The increase in the incidence of heart disease may be either due to the increasing tendency of thickening and narrowing of blood vessels or an increase in the levels of fatty substances like cholesterol and triglycerides in the blood stream, which contribute to the narrowing of the blood vessels.

It must be understood that no physician normally advises the use of pill for more than two years and especially not in women who have other risk factors. A similar study is being undertaken, shortly, in the Indian setting.

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Stronger cement-concrete

Any concrete structure is quite strong in compression but weak in tension. The use of reinforcing steel rods in concrete was the first step to improve the concrete properties and today reinforced concrete is a common application.

Newer and more demanding applications have led to more and more attempts to increase concrete strength. One such attempt is the development of concretes with water-reducing admixtures, which give a stronger, more durable material.

The function of water is to hydrate the cement compounds. On an average 23 per cent of water by weight of dry cement is required for the complete chemical reactions. The gel that is formed due to chemical reactions has a porosity of about 28 per cent and the pores obviously imbibe water. Research work has revealed that about 38 per cent water is required for the chemical reaction and for filling up of the gel pores. If water in excess of 38 per cent is used, capillary cavities form, resulting in loss of strength in the cement paste. But in actual preparation, more than 38 per cent of water is added to overcome the slow rates of hydration and for normal workability of the concrete.

Recent research (*Nature*, **289** 388) claims success in preparing concretes with only 22 per cent water on cement. These concretes were extensively tested and gave five to seven times flexural strength than of conventionally mixed concrete. The observations were confirmed by the flexural strength of concretes in which macro defects were deliberately introduced.

For practical purposes a mixing equipment which can mix cement-concrete with less than 22 per cent water without the loss of other properties needs to be designed. If this is achieved, new vistas may be opened up for the use of cement.

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V. C. MALSHE

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Between question and clarity

Anil Sadgopal

What is the role of science in a people's movement?

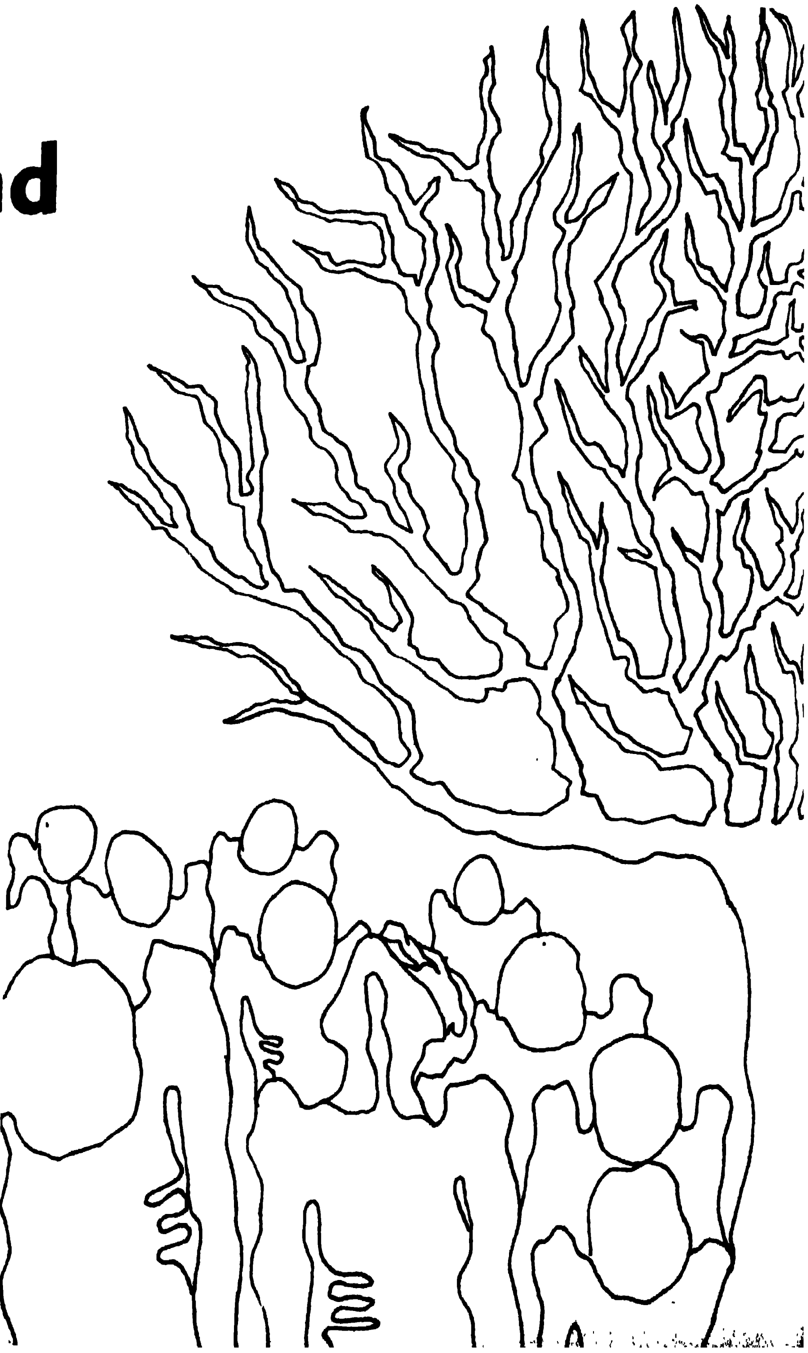
The ideas expressed in this article were first motivated by an article, "A Search for the Meaning of Science" by A. K. Roy (SCIENCE TODAY, October, 1979). The need for investigating the role of science in building up people's movements has acquired urgency in view of the growing interest in People's Science Movement activities all over the country. The ideas presented here may help to accelerate the ongoing debate among People's Science Movement activists on the content and pedagogy of their work.

Originally, this was the theme of a lecture delivered in April, 1980, in the 'Science and Society' lecture series organised by The Asiatic Society of Bombay. Based on comments received, it was revised to remove logical inconsistencies and to add more field experiences to emphasise some basic issues. What is presented here is essentially the Vikram Sarabhai Memorial Lecture delivered at New Delhi on August 12, 1981, under the auspices of the Indian Council of Social Science Research. In response to several questions raised by field-level workers during the last few weeks, certain clarifying paragraphs have been added to the original lecture.

LOCATED in village Palia Piparia of Bankhedi Block in the eastern tip of Hoshangabad district of Madhya Pradesh, the Kishore Bharati Group has conducted a wide variety of experiments concerned with economic growth, social organisation, youth involvement, and health and education, both formal and non-formal. Although the economic development and health programmes have been concentrated mainly within the Bankhedi Block and surrounding villages, the educational and youth involvement work has allowed us to interact not just with the people of Hoshangabad district but far beyond with various groups of people in other parts of Madhya Pradesh as well.

The focus of all of these activities has been to explore the fundamental causes of the severe poverty, exploitation and disparity in our society, and to evolve ways of resolving these contradictions. The strategy has been to subject all of our experiences to exhaustive scientific analysis with the purpose of evolving general principles which could have wider social application. This exercise of building up theoretical understanding through field-level practice has been further enriched by relating whatever we have learned with what government agencies, other voluntary groups, and people's movements have been learning in different parts of the country. For this enrichment, we must thank those hundreds of activists and thinkers who have more than willingly shared their experiences and analyses with us, and thus have made us a part of the nationwide struggle for social justice and development.

This article will also draw heavily upon the experiences of others, including those of government agencies, voluntary groups and people's movements. These experiences are used here as case studies for bringing out contradictions in our society and for evolving hypotheses for further experimentation. Nowhere these case studies are presented as personal criticism of people who are working in these organisations. Just like us, all such people must be engaged in their own battles against injustices, irrationality, stagnancy and other mechanisms of backwardness within their own organisations. Through

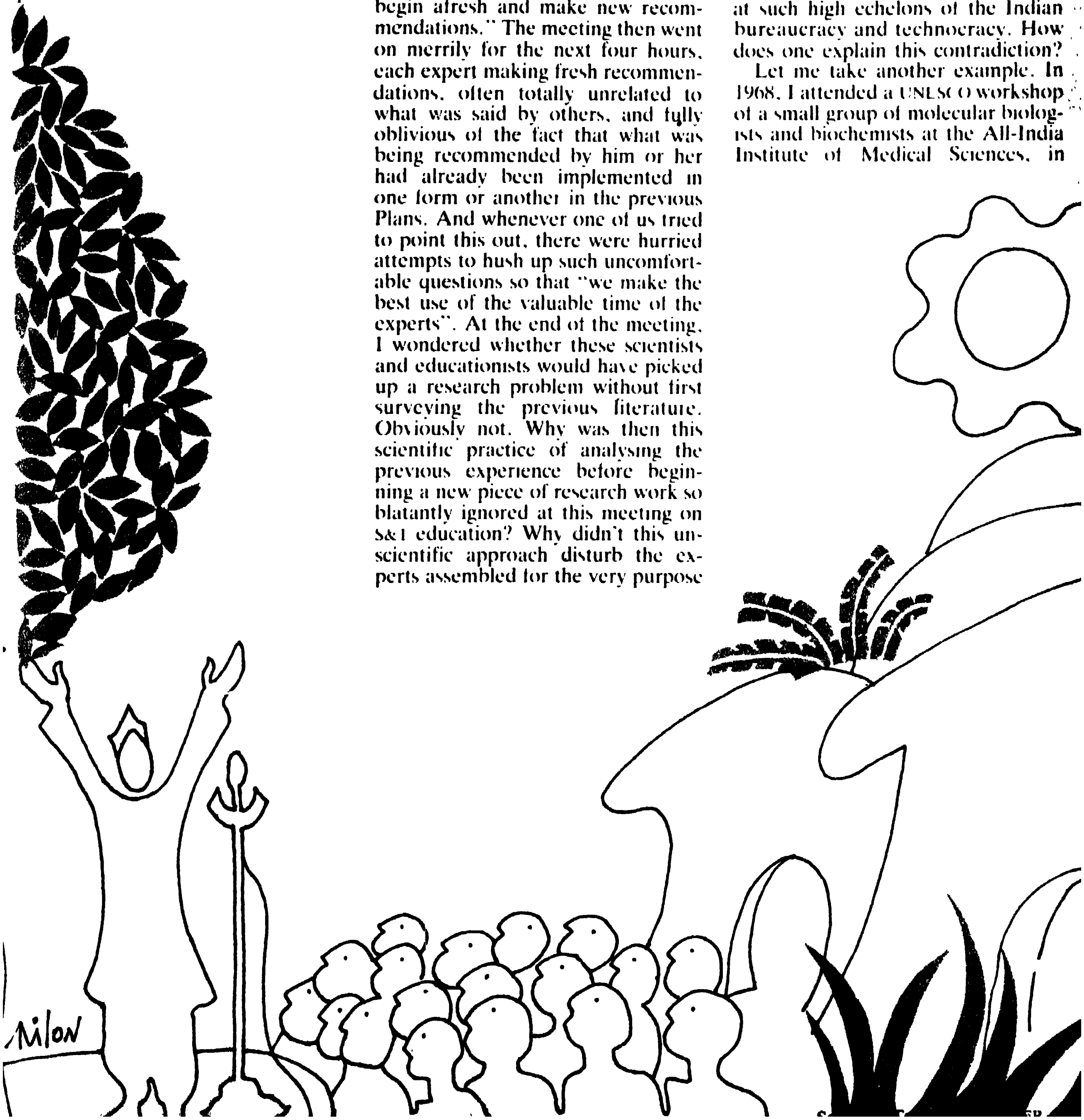


this article, I hope to do my little bit in breaking the isolation of these people and thus place their battles in a national perspective.

Let me begin with a meeting to which I was invited last year to review the science and technology (S&T) component of education in the context of the Sixth Five-Year Plan. The purpose of the meeting was to make recommendations to the Planning Commission to make S&T education more relevant to the socio-economic needs of Indian society. The chairman of the meeting began by inviting the experts to make their recommendations. One after another, the experts started reeling off their views on various schemes and ideas which needed to be implemented. After three such statements, a couple of us intervened and inquired whether a critique of the S&T component of education in previous Five-Year Plans was available. Of course no such critique could be produced. We then suggested that the meeting should first attempt to find out how the previous Plans had failed to relate S&T education to the needs of society. Only then would we have a scientific basis for making fresh recommendations, we argued.

What amazed us was the total lack of interest in the entire body of national experts who had gathered there to spend even a few minutes on this question. Judging the mood of the meeting, the chairman had to escape the dilemma by announcing, "We all know what was wrong with the previous Plans. We must now begin afresh and make new recommendations." The meeting then went on merrily for the next four hours, each expert making fresh recommendations, often totally unrelated to what was said by others, and fully oblivious of the fact that what was being recommended by him or her had already been implemented in one form or another in the previous Plans. And whenever one of us tried to point this out, there were hurried attempts to hush up such uncomfortable questions so that "we make the best use of the valuable time of the experts". At the end of the meeting, I wondered whether these scientists and educationists would have picked up a research problem without first surveying the previous literature. Obviously not. Why was then this scientific practice of analysing the previous experience before beginning a new piece of research work so blatantly ignored at this meeting on S&T education? Why didn't this unscientific approach disturb the experts assembled for the very purpose of improving science education? The story of this meeting is typical of all the meetings which I have had a chance to attend during the last several years—be it on adult education, or rural development, or bonded labour, or collective management, or appropriate technology, or the role of voluntary agencies. In all these meetings, there has been a commonality—a complete lack of interest in analysing the historical experiences not only of others but also their own, a general unpreparedness to learn from the past, and yet there has been an eagerness to make quick recommendations unmindful of the fact that these so-called new ideas have been part of the nation's previous experience. One is struck by the absence of scientific methodology at such high echelons of the Indian bureaucracy and technocracy. How does one explain this contradiction?

Let me take another example. In 1968, I attended a UNESCO workshop of a small group of molecular biologists and biochemists at the All-India Institute of Medical Sciences, in

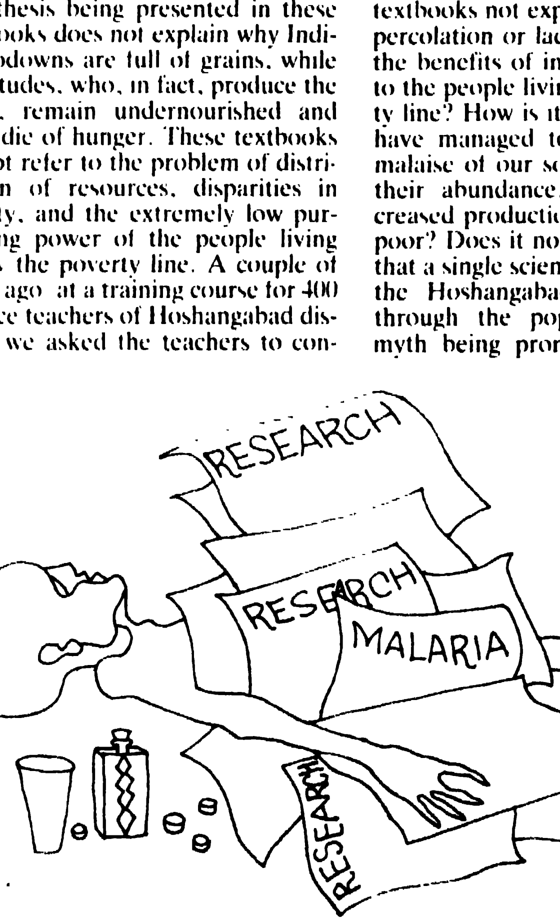


Delhi. At our request, a special meeting was convened to discuss the implications of the recent developments in the field of genetics on the policy of malaria eradication being followed in India and other Third World countries. Some of the leading authorities on malaria eradication from a national-level agency were called to discuss this issue. It was a time when highly disturbing reports about the reappearance of malaria were being received. The dream of seeing an India free of malaria was already being doubted. There was sufficient scientific basis to face the unpalatable fact of mosquitos resistant to DDT appearing on the scene. The biologists referred to the genetic mechanism of the appearance of drug resistance. It was explained that mutations leading to drug resistance appear randomly at very low frequencies, maybe one in a million. The drug may wipe out all the sensitive organisms except the mutant. The mutant would then reproduce making the drug ineffective. It was also explained how the simultaneous use of two or three drugs would reduce the probability of the appearance of drug-resistant mutants by a million times or more. The practical output of this theoretical understanding would be to add one or two more insecticides to the DDT spray.

The malaria experts were amused, to say the least. The seniormost amongst them politely pointed out that their concern was with practical programmes of eradication and not with biological theories, which, though founded on scientific lines, were of value only within the confines of laboratories. He further explained that the National Malaria Eradication Programme had been sanctioned and blessed by funds and technical guidance from the WHO, the DDT spray programme was running at full steam and no changes could be undertaken on the basis of theoretical concepts. When pressed by the biologists, the experts reiterated that even if a few resistant mosquitos had appeared, it would not matter since the programme was nationwide. "A few resistant mosquitos must not cloud our view," they stressed. The biologists lost the argument, but, as all of you know, resistant mosquitos have won the day! Why is it that the seniormost scientists working for malaria eradication ignored scientific arguments and biological facts? It is difficult to believe that they were not familiar with the genetic arguments advanced by the biologists. Why is it, then, that the malaria experts, and also such an august body as the WHO, pressed on with DDT spray? What is the fundamental reason behind this irrationality? It is unbelievable that even now DDT spray is being piously applied by malaria workers all over the countryside, when the entire body of scientists, not to speak of the public, knows that mosquitos are fast turning resistant. Equally unbelievable is the fact that respectable international aid programmes continue to support and encourage this waste of the nation's resources and attrition of manpower. And probably even more disturbing is the knowledge that leading technocrats and opinion-builders have turned a blind eye to this contradiction in the management of one of the most crucial health problems.

Let us take a third example to make sure that we are not talking of isolated instances; we are, in fact, referring to a national pattern. The textbooks recommended by a leading national agency carry a chapter on population to create awareness among the children about this critical national problem. We have analysed the population chapters threadbare. These chapters talk of the accelerating rate of population growth which negates the fruits of increasing production and thus creates poverty. The chapters argue that India's poverty problems could be resolved merely by controlling population and by increasing production. The thesis being presented in these textbooks does not explain why India's godowns are full of grains, while multitudes, who, in fact, produce the grain, remain undernourished and even die of hunger. These textbooks do not refer to the problem of distribution of resources, disparities in society, and the extremely low purchasing power of the people living below the poverty line. A couple of years ago at a training course for 400 science teachers of Hoshangabad district, we asked the teachers to conduct a survey of malnutrition in Hoshangabad and surrounding villages. The objective was to train these teachers in scientific methods of data collection and analysis on the basis of a problem existing in their own environment. When given this project, the teachers laughed, for they had been told that Hoshangabad district was surplus in wheat. How could there be any malnutrition, and that too in and around the district headquarters of Hoshangabad which is right in the middle of a wheat-growing zone? Maybe you would find cases of malnutrition in some remote tribal villages, one of the teachers pointed out. However, we pursuaded the teachers to go ahead with the survey. Within hours reports started pouring in about children suffering from severe malnutrition right in the midst of the town. By evening, the teachers had data to prove that malnutrition was characteristic of harijan and tribal sections of the villages.

We had then the scientific basis for raising the next question, "How is it that these children are suffering from malnutrition, while each village of the region is exporting wheat?" And then, suddenly, the brighter teachers asked, "Why is it that the textbooks teach that poverty is chiefly a result of population growth negating the fruits of production?" Should our textbooks not explain to children the percolation or lack of percolation of the benefits of increased production to the people living below the poverty line? How is it that our textbooks have managed to ignore this basic malaise of our society, that, despite their abundance, the fruits of increased production do not reach the poor? Does it not make you wonder that a single scientific survey enabled the Hoshangabad teachers to see through the population-production myth being promoted in our text-



books, while the irrationality behind this myth has escaped the attention of a leading national agency given the task of educating India's children?

One more example to substantiate the point which I am making. Three years ago, I was introduced to a British Council expert in the office of one of the heads of the departments of the National Council of Educational Research and Training (NCERT). The expert explained that he was in India to advise the NCERT on audio-visual aids, especially on the production of slide-cum-tape modules. I inquired whether he was aware of the conditions in Indian schools which lacked funds for buying even chalk and *taat-puttis*, or of the fact that most of the schools were beyond the reach of electricity and worked in single rooms often loaned to them by a local feudal landlord. The British expert showed awareness of all this. I naturally wanted to know the logical basis on which the British Council wanted to take up such an irrelevant activity in the Indian school system. The expert had no answer. Yet, during the last three years, the British Council programme has grown and spread. Hundreds of science education workers and experts have been trained and have become busy in feverishly producing fancy slide-cum-tape modules all over the country in teacher-training institutes and other science education centres. At a meeting of teacher-educators in Jabalpur in July this year, a number of such modules were exhibited with great pride, for these represented the entry of the teacher-training institutes into an advanced technology framework, having been given a large amount of modern equipment such as expensive cameras, projectors, and tape recorders under a foreign-aided programme. When anyone tried to find out what use would be made of these prize exhibits, there was always an uncomfortable silence. Another shocking effect of this kind of activity also emerged at the Jabalpur meeting. The language of the module was so highly sanskritised that it was totally incomprehensible to the primary school children for whom the module was prepared. Even the advice on better nutrition showed no awareness of the conditions of poverty from which these children came, since the module advised the children to eat plenty of fruits, vegetables, milk products and meat! When the attention of the experts was drawn to these gaps, a village teacher quipped, "Why do you worry at all? This material would never reach the primary school anyway." **This simple truth so well understood by the village teacher was apparently beyond** the comprehension of the national experts and international aid agencies who are behind this programme. The irrationality of this activity is further emphasised by our knowledge that the audio-visual teams presently engaged in producing these expensive modules have neither shown any interest in the past nor the ability for producing simple wall charts for classrooms! Suppose a question was raised in the Lok Sabha regarding this national wastage of energy and diversion of valuable resources, how would the NCERT explain the implementation of a programme which ignored the socio-economic conditions of Indian schools?

From all this, an impression might be emerging that unscientific traditions and irrational thinking characterise only the highly educated elite and thus constrain only the national-level agencies. The irrational processes, in fact, seem to pervade the rest of the society as well. Ten years ago, I attended an all-India conference of Sarvodaya workers at Nasik in the august presence of Jayaprakash Narayan. The conference had decided to start concentrated programmes for strengthening the *gramdan* movement. Each state was asked to select three districts for special effort so that the energies of all the cadres could be concentrated to show successful results. After this general session each state unit met separately. At the Uttar Pradesh meeting, the state-level secretary asked the workers to propose the names of three such districts. No one dared to speak. The secretary then suggested that Balia district should be the first to be selected "because JP was born in this district". He went on to propose that Agra could be the second district since the president of the state unit hailed from there. And the third district should be, of course, one to which he belonged. It was amazing to see the readiness with which almost 300 Sarvodaya workers raised their hands affirming the proposal. No one questioned the criteria of selection. An entire year's programme had been planned without any reference to the socio-economic conditions in a particular region, or to the availability of manpower, or to the potential response of the people. Why is it that the mere birth of Jayaprakash Narayan becomes a valid basis of selecting a district, and that this makes sense to hundreds of trained cadres? Does it not show a critical gap in the training of these workers or possibly in the entire tradition of Sarvodaya?

Constructing theory from practice

Let us now try to understand the basis of this widespread irrational and unscientific behaviour in our society. It is only with this understanding that we can hope to build a programme to resolve the crisis. I recall at this moment the first training course we organised in 1972 for 40 village science teachers of Hoshangabad district. On the very first day, we asked the teachers to measure the length of a table lying before them. A metre-stick in hand, each teacher went up to the table and carefully measured its length and recorded the reading on a paper slip. At the end of the exercise, the readings were transferred from the paper slips to the blackboard. Suddenly there was a lot of whispering among the teachers. Several of them stood up and protested against the results. The readings showed tremendous variation--from 98 cm to 108 cm.

A second attempt was made. This time the variation was reduced. The readings now varied from 100 cm to 106 cm. On the third attempt, the range of variation was from 101 cm to 105 cm. However, the truth was that the variation remained. It could be reduced by practice and improved skill, but could never be eliminated completely. There was a great deal of hue and cry among the teachers. How could it happen? Science was concerned with eternal truth, one teacher philosophised. "How could the truth be variable?" another demanded. Obviously, neither the table nor the metre-stick was changing in length, most of the teachers insisted. Year after year we have repeated this exercise with fresh batches of teachers until it has become an accepted feature for about six hundred teachers engaged in science education in the district's more than two hundred middle schools. That variation was intrinsic to all scientific observation is a concept which has been culturally and philosophically one of the most unpalatable for our science teachers.

The question is, therefore, whether such variation in observation is a phenomenon confined to natural sciences alone, or whether such variations characterise social sciences as well. We now have evidence of two kinds of variations in observation in social sciences. The first one concerns sampling errors. As an example, an interesting story needs to be told. Two years ago, we organised a youth camp to study the impact of severe drought affecting Madhya Pradesh. Some of the youth had surveyed the effect of drought on employment conditions. The data collected by them were being examined. One of them from the village Kamti remarked that there was hardly any unemployment problem in his village, for his data showed that labour was not available for digging wells. He gave precise figures of the wells awaiting completion. Immediately, another young fellow from the same village disagreed. He also produced data on the largescale migration of the landless and marginal farmers from the same village to find employment on railway lines and on PWD roads. A detailed analysis followed. It was revealed that both the young men had presented correct data.

What was the truth about unemployment? The difference in the two positions turned out to be the result of the different socio-economic background of the two persons—one hailed from a rich farmer background, while the other was a small farmer, living in the poorer part of the village. The first one found it difficult to get labour because his people either underpaid or did not pay at all, and also because they could not ensure long-term employment. The second one, being closer to the reality of poverty, had first-hand experience of a different kind. The particular social background of the first observer constrained his view, since it emerged from observations of partial reality of the richer few. Thus in social sciences, observational differences are often a result of the way samples are collected which in turn is a consequence of the socio-economic differences in the backgrounds of the observers. It is our contention that such errors can be corrected by scientific training as we were able to do during the youth camp two years ago.

There is a second source of observational differences, however, which seems to be beyond the realm of scientific training. Let us consider an example of this. I was a member of a small team sent by the Department of Science and Technology of the Government of India in 1978 to Orissa to do developmental planning for a cluster of five villages in Puri district. During our stopover in Bhubaneshwar, the government experts briefed us on the results of their survey of the same cluster of villages. We were told that the primary need of the area was for developmental programmes, especially a largescale cattle development effort involving artificial insemination centres, fodder cultivation, veterinary services and cattle feed supply networks. However, during our own survey, we were struck by the drought conditions and the extreme poverty of the region. How such a drought-stricken area could support a cattle development programme, we failed to understand. We asked a number of landless peasants working on the fields of others, "Suppose the Government is willing to undertake programmes according to your needs, what would you like the Government to do for you?" One of them pointed to the barren hillock nearby and suggested that the hillock be afforested. Another suggested that the contract of the local minor forest produce, such as *mahua*, should be subdivided into small contracts and be given to the poor people on bank loans, so that the rich contractors from the north did not take away their wealth. The third pointed out that the large tracts of the unused government land, as well as the land belonging to the rich people, be redistributed amongst the landless. Not one of them even mentioned a cattle development programme. What then was the basis of the briefing given to us at Bhubaneshwar? When pressed with our questions, the government experts told us flatly that we had been talking to the wrong people. They took us to the homes of a couple of rich farmers who gave us good refreshment and of course asked us to recommmend cattle development programmes to the government in New Delhi. Here was an example of observational differences in social sciences whose basis must be understood. When viewed from the perspective of rich farmers and the vested interests of government experts, largescale and well-funded development programmes appear to be the need of a region. However, when viewed from the perspective of massive poverty, redistribution of resources and changes in management practices of the existing resources appeared to be the need. There is a wealth of evidence to show that such differences are related to the vested interests dominating the social structure. Scientific training can be of little help in such cases.

It is our experience that whenever confronted with economic interests and questions of socio-political power, scientific processes often reach their limits. We have gone deep into this subject, and have been amazed by the widespread influence of this type of observational differences on the very directions and priorities of rural development. We first became aware of this malaise of development programmes through one of our own experiences. We had organised a small cattle development programme, including a cross-breeding service, in Bankhedi in 1972. We had been advised by some of the leading authorities concerned with milk co-operatives and cattle-breeding that milch cattle was the most suitable cottage industry for generating massive rural employment. Successful examples of Amul in Kheda district of Gujarat and of Bharatiya Agro-Industries Foundation at Uruli Kanchan in Pune district of Maharashtra had often been quoted to us. After three years of this work, we looked at our data to see who were the people who had benefited from the cross-breeding service. We found that most of the beneficiaries were well-to-do farmers and successful lawyers or *banias* from a nearby town. A small number belonged to the middle farmer class. No one had come forward for cross-bred cattle from the marginal farmer and landless classes.

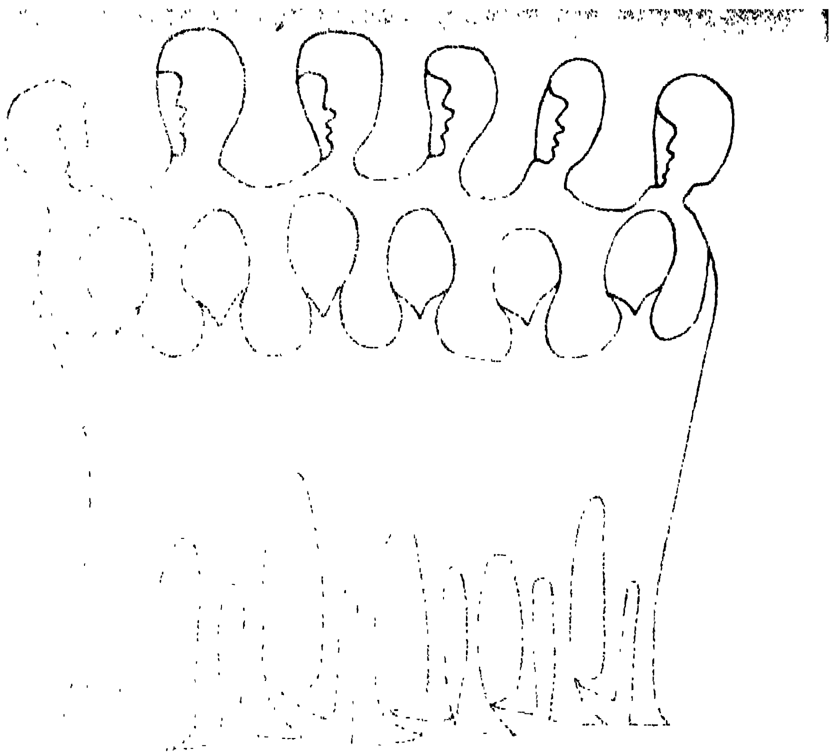
How would such a programme help the rural poor, we wondered. We were upset by these data and decided to check with another local voluntary agency also involved in cattle-breeding. Their experiences matched with ours, although this agency worked in an irrigated region and had easy access to the markets of the towns. However, we were continuously reading newspaper reports and hearing seminars in which a reputed voluntary organisation was claiming that the benefits of cattle-breeding are distributed among all classes of the rural population. We then decided to look at the registers kept at the insemination centres of this voluntary agency. There was a big gap between the public claim by this agency and the data in its registers. Here, too, the poor sections of population were again excluded from the cattle-breeding benefits. Why, then, did this voluntary organisation as well as several important government agencies continue to present cattle development programmes as a means of solving rural poverty? Nowhere do we read analyses showing the differential impact of cattle development on rural people. Why is it that our observations do not match with the observations of several leading agencies of the nation while the reality in all such experiences is the same? It appears as if there is a conscious effort to suppress and mutilate certain kinds of observations in social sciences.

There is growing evidence to this effect. Last year, All India Radio, Bhopal, interviewed us. During the interview we narrated our experience of cattle development. The first part of the statement referred to the number of beneficiaries, to our attempts to popularise fodder and to spread knowledge of animal husbandry. In the second part of our statement, we pointed out how the programme had failed to make any impact on rural poverty. The taped interview was taken away by AIR and we were dumbfounded when it was broadcast a week later. The first part of our statement presenting a glamorous view of our work was broadcast, but the second half was methodically excluded. This experience should help in understanding the experience I have narrated from Orissa. It is not a question of a lack of scientific method in our thinking. It is clearly a question of confrontation with vested interests which prevents scientific processes.

Besides the matter of scientific observation, the second dimension of the method of science is concerned with analytical thinking, or the logical process. Let us examine its role in social sciences. Once again I would narrate one of our experiences. Along with our cattle development programme in 1972, we introduced a new technology of digging irrigation wells in our area. These wells, called ring wells, are made up of prefabricated concrete rings which are sunk in the ground and are able to tap the aquafer in the same way as tubewells. Inexpensive, technologically within the means of a rural community and constructed in two weeks' time, ring wells are a textbook example of appropriate technology. (The ring well technology was evolved more than 20 years ago at the Friends Rural Centre, Rasulia, Hoshangabad, and spread rapidly in the surrounding region. However, for various reasons, the technology of ring wells did not reach the eastern region of Hoshangabad district until 1972.) As a result of our work, ring wells have spread in more than 100 villages in and around the Bankhedi block and about 450 such wells are already irrigating approximately 5,000 acres of land, thus generating new employment and changing one-crop zones to two- or three-crop zones. Despite these optimistic observations, our group subjected the data to further analysis. This revealed in 1977 that the wells had then increased the annual agricultural production of the area by Rs. 12.5 lakhs. Out of this additional annual income, Rs. 9.5 lakhs had gone to the 300 farmers who then owned the ring wells. The remaining Rs. 3 lakhs were distributed amongst a couple of thousands of farm labourers. Obviously much more had gone to the landed few and much less to the large number of landless in the area. We concluded thereby that the production of ring wells, though benefiting the region in an absolute sense, was at the same time increasing the gap between the rich and the poor.

The realisation of this limitation of agricultural development as a means of solving rural poverty forced us to explore alternatives. We examined the case of cottage industries as an instrument for generating rural employment. A number of exploratory projects such as carpentry and manufacture of electric chokes were undertaken. In addition, markets were surveyed to assess the potential of selling a variety of cottage industry products ranging from soaps to *agar-battis*. The size of local markets for indigenous shoes and ready-made clothes was also assessed. The results of this entire exercise were compiled and analysed. We discovered that a total of about 20 cottage industries could generate jobs for only about 100 poor families in the Bankhedi block consisting of 125 villages and more than one lakh people. Obviously a drop in the ocean. We also found out that most of the transactions in the village markets involved the well-to-do and the middle classes. The poor, despite their vast majority, had only a small share. Experience and analysis also revealed that the limited potential of cottage industries in rural areas had little to do with the lack of knowledge of modern technology, or with low trainability, or with meagre managerial skills, but it had more to do with the limited capabilities of markets. The low purchasing power of the vast majority of the people living below the poverty line and the domination of village markets by competitive goods from urban middle-size and monopolist industries defined the boundary conditions of the rural marketing system. Despite this glaring reality, the Government agencies and several voluntary groups continue to glamorise the role of cottage industries in rural development. Why has this reality been so systematically ignored by so many groups and agencies over the last several decades? Why is it that this simple analysis of the limitation of cottage industries has not been presented from public platforms by the government departments of industries and a large number of voluntary groups? What could be the possible reason for the silence of the Planning Commission on this crucial question? Is it that the educated elite and the national leaders are incapable of the needed logical exercise or is it that the socio-economic crisis and the insoluble problems of rural poverty make it too dangerous to scientifically accept this reality?

What concerns us is not the limitations of cattle development, or of irrigation programmes, or of cottage industries as instruments for solving India's poverty, but the fact that an analytical view of rural development problems is not being shared with the people of this country. Our brief experience has revealed to us that the rural society is critically divided into two sections — a small minority of the rich and middle-level farmers which siphons off the benefits of development programmes and has vested interest in their continuity, and a vast majority of the landless, marginal farmers, and artisans which is excluded from this process and is generally not influenced by what goes on in the Planning Commission and the agencies or departments concerned with industry, development, and science and technology. Whenever somebody preaches rural development, we always want to understand whose development is being talked about. Is one referring to development of the moneylender or of the rich farmers or of the marginal peasants or of the landless labour? When such analysis is negated, it leads to the typical confusion which is reflected in such questionable phrases as the *rural-urban gap*, or *planning from below*, or *community development*, or the *panchayati raj*, or *people's participation*. Such phrases presume the existence of a homogeneous community or imply that the poor do not exist in cities and the rich do not live in villages. It is our contention that as long as a scientific analysis of India's development experience is avoided or suppressed, the basic premise of the entire planning process shall remain untenable.



Regarding scientific analysis, there is often loose talk about this process being the exclusive preserve of the educated elite. Our experience of non-formal education has given us sufficient evidence to challenge this grave misunderstanding. I am reminded of a brief interaction with a representative of the Khadi Gramodyog Commission who once met me accidentally in a bank office. He was looking extremely unhappy. On enquiries he revealed that his main job was to popularise the electrically operated potter's wheel, nicknamed power *chak*. He was disturbed because, despite his hard work, no potter was willing to accept a power *chak*, although he was offering subsidies, low interest credits and all other necessary support. I asked him if he could explain his failure to popularise what he called appropriate technology. He said that the people of this district were uneducated and did not understand modern technology and, therefore, rejected the power *chak*. He had reached a conclusion which was typical of what is widely accepted by the educated elite. I decided to help him to unravel the situation. On being questioned, he readily accepted that the potters he had met in villages had difficulty in selling what they produced on their *chak*, and therefore were often without business. I asked him to explain how the power *chak*, meant for increased production, would help a potter who was already unable to sell his products. What was the potter's problem — the market or his ability to produce? The khadi commission's representative gradually began to see the logic and accepted that the Commission's example of appropriate technology was, after all, not so appropriate. The uneducated potters on their own had conducted a logical analysis of the conditions which constrained them from earning more, and, therefore, had a scientific basis for correctly assessing the role of power *chak* in their lives, something which the experts in the khadi commission had failed to do.

Let us consider a recent experience. A group of about one hundred landless and marginal farmers from an adjacent village approached us last month to explore a new path for solving their problems of poverty—they needed land, rights to certain minor forest produce and demanded a fair share in the distribution of government-controlled sugar. They had decided to organise themselves and challenge the control of the feudal forces on their lives. We pointed out to them the risks involved in this path and drew their attention to how their attempts to improve their conditions could be quashed by the joint action of the local landlords, the revenue authorities and the police. This was of course already well-known to them. We demanded to know from them what they felt was their bargaining point. One of their leaders, who could not even sign his name, gently pointed out, "It is *we* who produce goods and *they* consume only what we produce for them. If we stop working, they shall starve. This is our bargaining point." We have accumulated a series of such experiences which show that the poor people who suffer oppression and exploitation have remarkable abilities for participating in a growing analytical process and have often amazingly correct analysis of the obstacles in the path of their own development.

Framing hypotheses for further testing

From all this, we would like to postulate five significant hypotheses. These are being postulated in the hope that these will accelerate experimentation and further testing to evaluate their validity or the lack of it. At this stage, these may be regarded, at best, as tentative and partial.

i) Correct observation and scientific analysis are essential tools for comprehending the socio-political reality around us.

ii) There are more ways than one of observing the reality in social sciences. What aspect of the reality one perceives is critically related to one's cultural and economic background. In contrast, the process of observing and analysing reality in the natural sciences is dependent only on the scientific skills of the worker, and not on his or her class background. Here one is referring to the areas of research emerging from the needs of the internal structure of the various disciplines of natural sciences, and *not* to the areas of research concerned with the application of science to the needs of society. The moment one begins to relate science to the problems of society (for example, in the case of technology), the class affiliations and the vested interests of the worker begin to influence his or her objectivity in a manner similar to what we have discussed in the matter of social sciences.

iii) The ability to make correct observation and to conduct analysis in the natural sciences can be developed through training. However, in the field of social sciences, the attempts to improve observational skills and analytical abilities often do not succeed when there is a clash of vested interests. Thus there are inherent factors in the social sciences which limit the application of the scientific method.

iv) The potential for scientific processes is not confined to the elite and the educated sections of our society. Such potential exists amongst the oppressed and the uneducated people and can be further enriched through training and experience.

v) The process of socially relevant planning is one in which the planners work with the oppressed people to develop a scientific basis for observation and analysis. Without establishing such a process, the dichotomy between today's development and social change programmes, on the one hand, and the lives of the oppressed people, on the other hand, will never be bridged.

These hypotheses help us to define the role of science in building a people's movement. As we understand it today, the primary role of science is in enabling the people to comprehend the socio-political reality of their environment through the scientific method so that their struggles for justice and development can be planned on the basis of reliable data and logical thinking. The process of education is thus defined as the process of spreading the method of science among people to enable them to understand the obstacles which prevent their development and successfully plan their struggles for justice.

If the role of science in people's movement and the educational process as understood by us today is acceptable, we may then contend that it would be essential to spread the scientific method for the purpose of training cadres and creating people's organisations. How is this theoretical understanding of the role of science and of the educational process to be implemented in field situations? What have been the experiences in doing such work? What are the obstacles in developing this educational process with people? In order to explore answers to these questions we must first break down the scientific method into its essential elements. Desire to know or inquisitiveness, observation, data collection, analysis and inference are some of the elements on the basis of which an educational programme may be conceived.

Let us take a concrete example. Early this year we organised a youth camp around the problem of tuberculosis in villages. The young participants were asked to survey the incidence of tuberculosis, its relationship with the working and living conditions of the people, the role of the National TB Control Programme and limitations imposed by social structures on the treatment of the disease. For several days, the participants toured villages in teams, collected data, listened to agonising stories of whole families being wiped out by the disease and of the role being played by government doctors, private practitioners and feudal forces. The entire data was compiled teamwise and then the teams were asked to make a list of all the problems which they had perceived during the survey. From these teamwise lists a common list was then prepared on the basis of which a detailed discussion followed on the causes of TB, of its high incidence amongst the poor people and of the inability of the Primary Health Centres to play an effective role in the treatment. The discussion focussed on the reasons behind the non-percolation of the benefits of the National TB Control Programme and what it reveals about the structure of village society. On the basis of this analytical understanding, the youth camp concluded that there was no use in starting a parallel medical service while a full-fledged national programme existed. It was much more important to make the people aware of the facilities available under the national programme and to enable them to demand their share in this. This example of educational process shows us how a group of young people planned the next phase of their activity by applying the scientific method to their experiences.

Obstacles in the educational process

In the process of spreading the scientific method among the oppressed people, we have identified five major obstacles: information gap, the tendency to follow traditions, fatalism, fear of reprisals by the vested interests, and inability for abstraction.

It is a general experience that lack of information among the oppressed people is often a great limitation in understanding their own reality. When this gap is filled, ability to comprehend reality builds up quickly. This is exemplified beautifully by the work of the Kerala Shastra Sahitya Parishad (KSSP). The KSSP took up the problem of pollution caused by a well-known rayon factory in Walcad village near Calicut. This factory, located on the banks of the river Chaliar, has totally polluted the river as well as the air. The people of Walcad village have suffered heavily in their health, in their farming and in many other ways. Yet for years they accepted their state of affairs with only grumbling and not much more. The KSSP encouraged students of Calicut Medical College to organise a health survey. The survey revealed a high incidence of a particular lung disease caused by the presence of sulphur dioxide and carbon monoxide. The KSSP then sent a team of biologists, chemists, geologists and engineers. The team prepared a massive report and took colour slides of the polluted river and finally prepared a technical plan for controlling pollution. On the basis of all this, the KSSP conducted intensive evening classes for several weeks to share this rich information with the poor people of Walcad village. When we visited this village last year, we were amazed to see how technical terms such as sulphur dioxide, carbon monoxide, percentages and solubility had become part of the common idiom. The evening classes soon led to the demand by organised villagers that the factory implement KSSP's technical plan for controlling pollution. The long-drawn struggle eventually cornered the powerful industrial group which had no logical way of escaping from this demand without losing its credibility in Kerala. The technical plan is now being implemented and the people of Walcad have at least won their first battle.

The second obstacle of the educational process is the deep-seated tendency to follow tradition. I am reminded of a play prepared by two young villagers of Rohna village near Hoshangabad. These boys belonged to an area which has been affected in a major way by the famous Tawa irrigation dam. The Tawa programme has led to many unanticipated problems, such as creation of waterlogged areas, loss of fertile soil and lack of drainage. In addition, the Government passed an Act which has been used to pressurise and compel farmers in the Tawa command area to accept land-levelling operations conducted by government agencies. The expense of this operation is charged to the farmer. Of course, bank credit is extended to cover the charges, normally ranging from Rs. 1,000 to Rs. 2,000 per acre. The farmers feel tremendous hardship because of being forced to accept this indebtedness. The play referred to this problem. In the first few acts, the boys presented the collusion of the revenue officials with the local landlord in persuading the villagers to accept a plan of reconsolidation of land holdings before undertaking levelling operations. In the process, the landlord corners most of the fertile land which earlier belonged to the poor farmers and the revenue official takes his bribe. Later on, the play focusses on the indebtedness caused by the land-levelling operations and has a scene in which the tehsildar is helped by the police to force the villagers to pay their first instalment when their crops had failed because the fertile soil had been disturbed by land-levelling. So far the act shows a close relationship with the reality which exists in the villages of this region. In the last act, the play shows the villagers pleading with the district collector for relief. The collector is extremely helpful, is disturbed by the inhuman acts of his tehsildar and of the corrupt revenue officials. He promises immediate relief and orders suspension of the erring officials.

We asked the boys whether the last act matches with their real experience. After hesitating, they accepted the fact that the collector rarely acts the way he is shown in their play. "Why then did you show this untrue picture of the collector?", we inquired. One of them explained that all stories and films end well and therefore they must end their play also on a happy note. The second pointed out that it would look very bad if the seniormost official of the district is not shown favourably. They had been taught to show respect towards authorities. Having shown some challenge towards the lower officials, they eventually decided to fall in line when the collector's turn came, lest their elders should reject the play.

The third obstacle is the deep-rooted fatalism in our society which often restricts the growth of the scientific process. I am reminded of a *basod* (a Harijan bamboo worker) who earns his livelihood by making bamboo products. I once saw him without work at a time when he should have had a big supply of bamboo from the local forest depot. When quizzed, he explained that all the bamboo had been sent to the distant paper mills at Nepa Nagar. This uneducated *basod* obviously was well-informed. I prodded him, "How come one paper mill takes all the bamboo away, while thousands of poor *basods* like you are deprived?" He was emphatic, "Nepa mills are more powerful than all the *basods* put together." I asked him if there was any way in which the *basods* could balance the power of the Nepa mills and demand their share of bamboo. He said it would be possible only if they got organised and approached the forest depot collectively. I asked him, "Why don't you do this?" He said, "No, it is not possible. We will never get together. It will take no less than God to bring us together on a common platform. Therefore, this year bamboo is not in our fate." Having given a series of logical and well-informed statements, the *basod* finally reached the end of his scientific process. The limit was clearly defined by God and fate together.

The fourth obstacle is the fear of reprisals by the vested interests. The impact of this fear cannot be fully appreciated unless one is involved in the daily lives of the oppressed people. Two years ago, we proposed a programme to a group of *Rajhar* adivasis of a nearby village through which they would be able to gain rights to grow lac on *kausam* trees which happens to be their particular profession followed through generations. So far they had acted as daily wage labourers and grew lac on behalf of big landlords or contractors. Their long-cherished goal was to gain rights to grow lac on their own. Yet when confronted with an opportunity to gain these rights, no one came forward. We learned later that our evening meeting with the *Rajhars* was followed by severe threats of being beaten up or lynched by the local landlord, who also happened to be the *sarpanch,* in case they insisted on going ahead with the programme of growing lac. Most of these *Rajhars* are either indebted to one of the feudal families in the village or work on their farms as labourers. The feudal families were concerned that their economic and political control would be weakened if the *Rajhars* gained economic independence. For two years, we waited for the *Rajhars* to respond. No amount of scientific analysis of the causes of their poverty and of the manner in which owning the lac business would alleviate it would help bring out a response.

Then, suddenly, an unplanned and a totally unrelated incident changed the entire picture. In May this year, government controlled sugar was distributed in the village, as usual, unfairly, the poor people being deprived of their fair share by the *sarpanch* or the landlord. For the first time, in local history, a group of villagers gathered courage and approached the landlord to seek justice. Incensed by the collective courage shown by the villagers, the landlord got a couple of adivasis beaten up. There is nothing unusual about such incidents which have been traditionally accepted passively. This time, however, we intervened. The *sarpanch* was forced to call a public meeting at which he tendered unconditional apologies. Those of you who have personally experienced feudal India would probably appreciate the impact which this meeting must have made on the minds of the poor people. What two years of continuous discussion with *Rajhars* and all the application of analytical thinking could not bring about was achieved suddenly by the emotional impact of the sugar incident. For once there was a real experience to show the people that feudal power was after all not invincible. The limits of scientific method were thus broken. The *Rajhars* came forward last month to join hands with other oppressed people of the village to become organised, to break out of a century-old feudal framework, and to gain their rights to grow lac on the *kausam* trees. The scientific processes can once again be initiated and taken to new heights.

It is our common experience that the obstacles posed by the factors of tradition and fatalism, discussed earlier, are overcome by similar processes. The field experience reveals that these obstacles of tradition and fatalism are also normally overcome either by the emotional impact of certain events or by the liberating effect of certain changes in the socio-economic conditions as a result of historical developments, rather than through strictly a logical and predictable process. The educational work of spreading the scientific method does not progress as long as such barriers continue to exist, but can be started all over again once these barriers have been broken by mechanisms which are beyond the realm of science.

The fifth and the last obstacle is the problem of abstract thinking. Let me again refer to KSSP's work in Walcad village. Towards the end of our visit, we informed the Walcad people that there was an identical problem of river pollution in Shahdol district of Madhya Pradesh where a paper mill owned by the same industrial group had polluted Sone river downstream. This problem has been investigated and reported in detail by *Vidushak Karkhana*, a group of engineer-activists working in Anuppur Block of Shahdol district. The Walcad people showed no interest. Shahdol and Sone river were too far away, too remote to have any meaning for them. We then asked them if they perceived any relationship between the local rayon factory and the government in Trivandrum. Again there was a disturbing silence. Trivandrum did not have much meaning in their local struggle for justice nor could they see any possible relationship between the factory and the government far away. Here is a problem of inability for abstract thinking which is going to constrain the building of a people's movement more severely than has been probably anticipated or consciously understood so far. Yet there is evidence that the potential for abstract thinking does exist among the oppressed people. An example needs to be cited.

In Thane district of Maharashtra, an adivasi movement called *Bhoomi Sena* has taken lead in seeking justice for the oppressed people. Representatives of about 100 village-level *Tarun Mandals* once gathered to plan for their next strike, against the rich farmers, for better wages. An interesting question was raised. How do the *Tarun Mandals* look upon other sections of society, namely, small farmers, middle peasants, landless labourers, and so on? Each representative gave his perception of who is a friend of the movement and who is not. Stories were narrated of incidents bringing out the character of various groups. All of these statements were analysed and an amazing inference was drawn. The conference concluded that the middle level farmer is not a friend of the movement, since he employs others to do farming just as the rich farmers do. However, the small and the marginal farmers who work on their own farms as well as seek employment along with the landless in the lean season must be considered friends, since they are also exploited just as the landless are. Some one pointed out that the poor farmer is in fact exploited twice—once when he seeks *khaoti* (a form of loan) in the lean season from the moneylender along with the landless, and the second time when he seeks loan in the form of seeds. The conference therefore reached a new understanding: in the next strike, small farmers would be persuaded to join hands. Here is an example of the possibility of abstraction from simple experiences, of building up general principles from daily lives. This process of generalisation and creating principles from practice would be a critical dimension of spreading the scientific method.

Towards a people's movement

If we can learn how to overcome the five obstacles to the educational process, we can see a powerful and growing process of education emerging. If the methods of science can thus be made part of people's thinking, there is hope that the domination of the educated elite and of the vested interests in the field of planning and development can then be challenged by the common people. If the oppressed people begin to subject the policies of the nation to scientific analysis, there is hope that a constraint can be placed on the irrationality revealed in the S & T education meeting held under the auspices of the Planning Commission, on the unscientific planning of critical health programmes such as malaria eradication, on the myth being promoted in our school textbooks about population growth being the prime cause of India's poverty, the introduction of irrelevant activities, such as the slide-cum-tape modules in our school system and so on. There would be then hope that the personality cult and sycophancy reflected in the Sarvodaya conference and similar feudal tendencies prevalent in national life would no longer be quietly accepted. Scientific criteria would necessarily be demanded from the leadership for its statements, acts and decisions. If the critical dimension of abstraction could be added to the analytical processes of the people, the people of Walcad village would be able to relate their oppression with the oppression of the people of Shahdol, and the linkages between the industrial group owning the rayon factory in Walcad, on the one hand, and the governments in Trivandrum and New Delhi, on the other hand, would become clear to the people of the country. People's organisations built up through scientific processes, hopefully, will not limit their struggles to demands for merely better wages or land, but would instead struggle for ways of creating and sustaining a society relatively free of disparities, exploitation, stagnating heirarchies, and other mechanisms of socio-political backwardness. This would then mark the creation of a people's movement with a difference.

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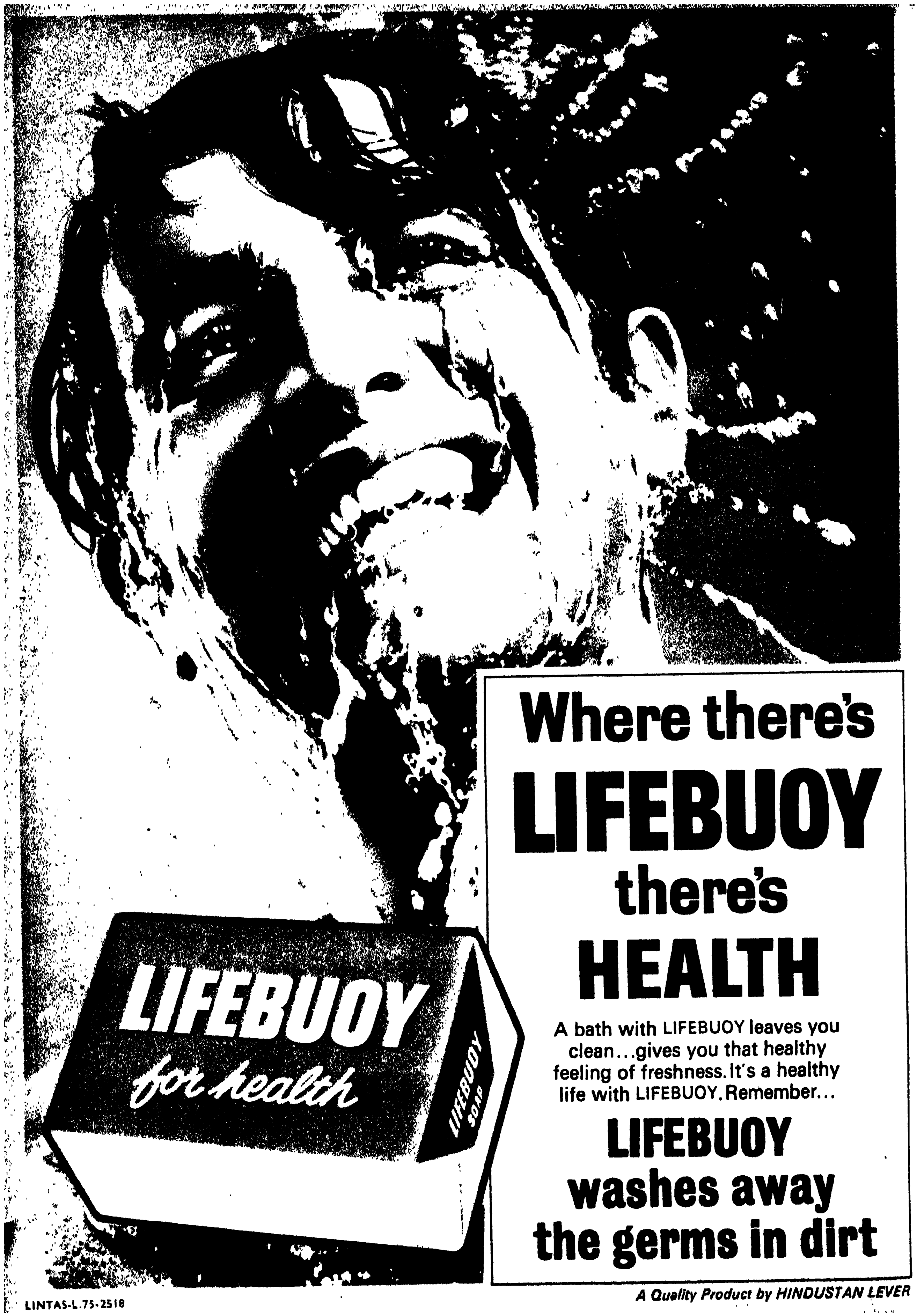

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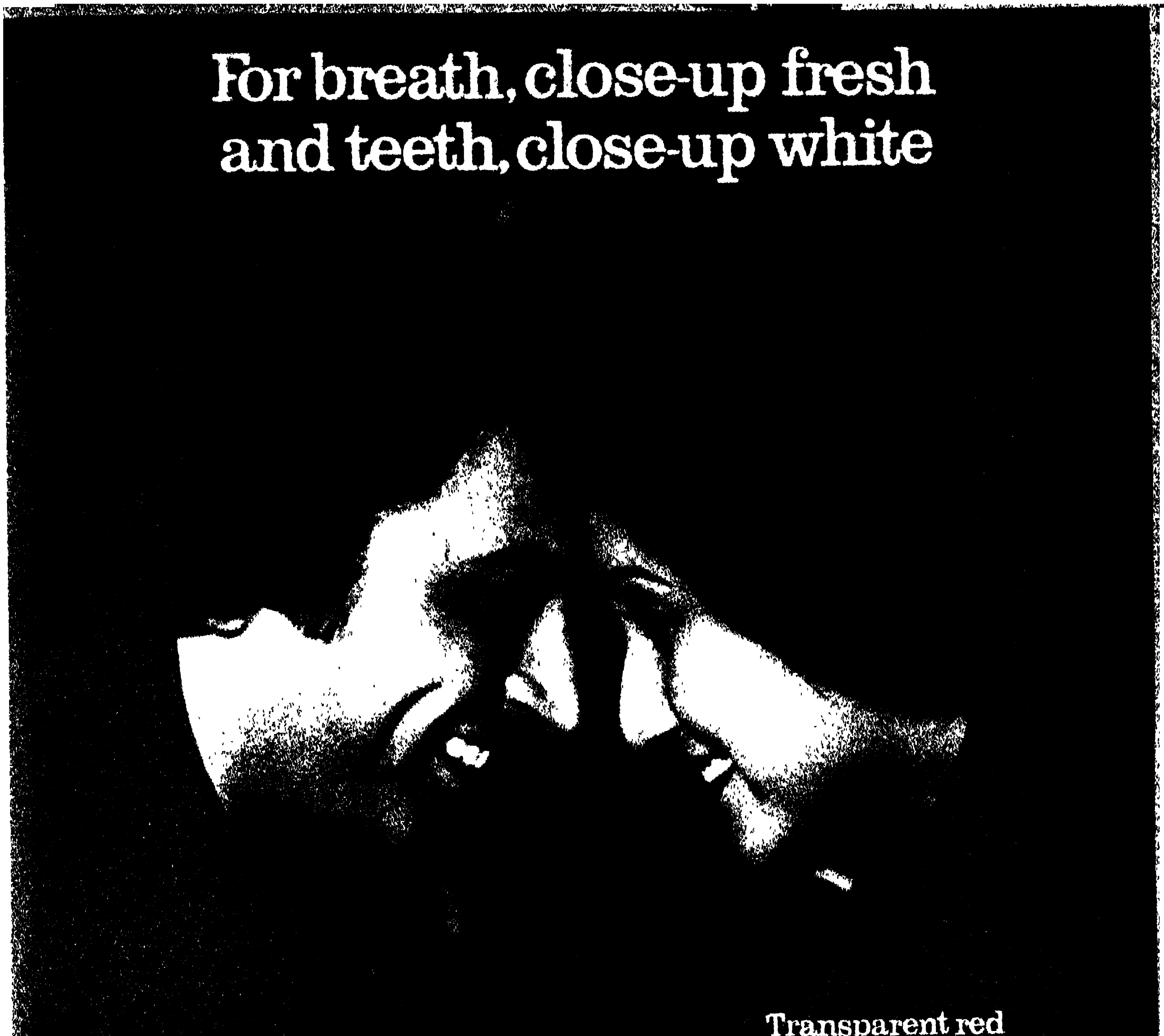

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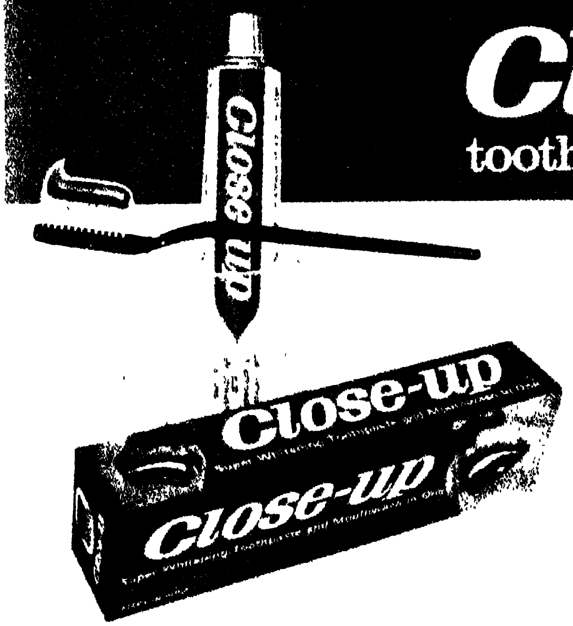

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Rollers ease bullock pain

NINETY per cent of the draught animals being taken to veterinary hospitals today suffer from neck diseases. The reason is that the animal-drawn vehicles in use put much more load than necessary on the animal's neck. A simple device that takes care of this problem with the help of rollers to balance the load is proposed below.

Bullock carts are the most predominant among the 13 million animal-drawn vehicles in India. Animal-drawn transportation absorbs an estimated investment of the order of Rs. 30,000 crores and employs about 20 million people directly or indirectly. Bullock carts carry roughly 10,000 million tonnes, the bulk of the rural produce, to the mandis each year. Capital investment on a bullock cart is very low and for country roads and short distances, the bullock cart is still preferred.

A bullock cart, simple though it may look, poses a host of problems in the process of being modernised. Some headway has been made in redesigning the cart but the changes, especially the use of pneumatic types, have brought additional problems, for example, the traditional wheels with their large diameter could skip over pot holes, but smaller ones get bogged down. Considering the unsuitability of the pneumatic tyres for country roads, the traditional cart with its two big wheels will be the only type that would continue to ply on country roads.

The part of the cart most difficult to redesign has been the harnessing device for which no satisfactory design has yet been found. The prevailing method of transmitting the bullocks' power is inefficient and also cruel for the animals. The third point of the load of the cart falls on the neck of the animal with the other two on the two wheels. So long as the load in the cart is balanced on the two wheels and the cart plies on a level track the vertical load on the neck of the animal is small and steady and the bullock can bear it without pain. Actually the country roads are quite sloppy and rarely level due to rivers, rivulets, hillocks and uneven terrain.

Even if the cartman loads the cart properly, the load on the animal's neck increases while plying on down gradients with considerable pain and injury to the animal. The cartman, with no means to balance the load on sloppy terrain, helplessly connives at the torture the animal is put to, and has to force the animal by merciless flogging. An upward pull on the throat of the animal will suffocate and may even kill the animal. So a cartman always keeps much more load than necessary on the neck, as a safeguard against the animal's suffocation. This additional load results in further wastage of effort. The animal soon gets fatigued and eventually his neck skin peels out.

A device that can maintain a steady and easy load on the animal's neck is therefore sorely needed. The device proposed below is simple and sturdy. The cartman can operate it from his seat and balance the load instantly when needed. It is light, weighing about 70 kg and yet balances the load of a fully loaded cart. It is cheap and does not hinder the movement of the bullocks and keeps ample ground clearance on village roads.

The device consists of four cylindrical iron rollers, each nearly 20 cm long and nearly 10 cm in diameter. These rollers can roll from the front end of the cart to the rear end and vice versa in a frame. The angle iron frame is fitted under the chassis of the cart and is hinged at the centre of its length and suspended on the axle of the cart wheels. With this arrangement the free ends of the frame can move up or down.

When the front end of the frame is raised, the cylindrical rollers roll by gravity to the back side of the cart. Similarly when the front end is lowered, the rollers roll from the rear end to the front end. The cartman can raise or lower the front end of the frame by hand through a lever, fitted in front of the cart. The lever has a lock pin, which automatically enters the hole on the cart chassis.

Reducing vertical neck-load in bullock carts

IN animal-drawn vehicles, a vertical load undoubtedly acts on the animal's neck, because shock loads caused by uneven terrain are not absorbed by the yoke in prevalent designs. Several papers published by the Indian Institute of Management, Bangalore (IIM-B) have drawn attention to this problem. At present, not only does the animal's neck bear the extra strain of ascent and descent, but is also cruelly employed for braking and turning in double-bullock carts.

Three notable alternatives to the present wooden yoke have been tried out. The first is a horse-type harness which does away with the traditional yoke altogether. Extensive trials at the IIM-B show, however, that this involves early work-training for the draught animals if they are to accept the harness. There is still scope for further work in this direction.

The second alternative is an IIM-B prototype, shown at the Indian Road Congress Exhibition, Bangalore, during 1979, which has sought to reduce the vertical load on the animal's neck, by using spring steel in the yoking device. In many cases the problem could be further tackled by using a single animal with an improved cart of the same capacity as the traditional one.

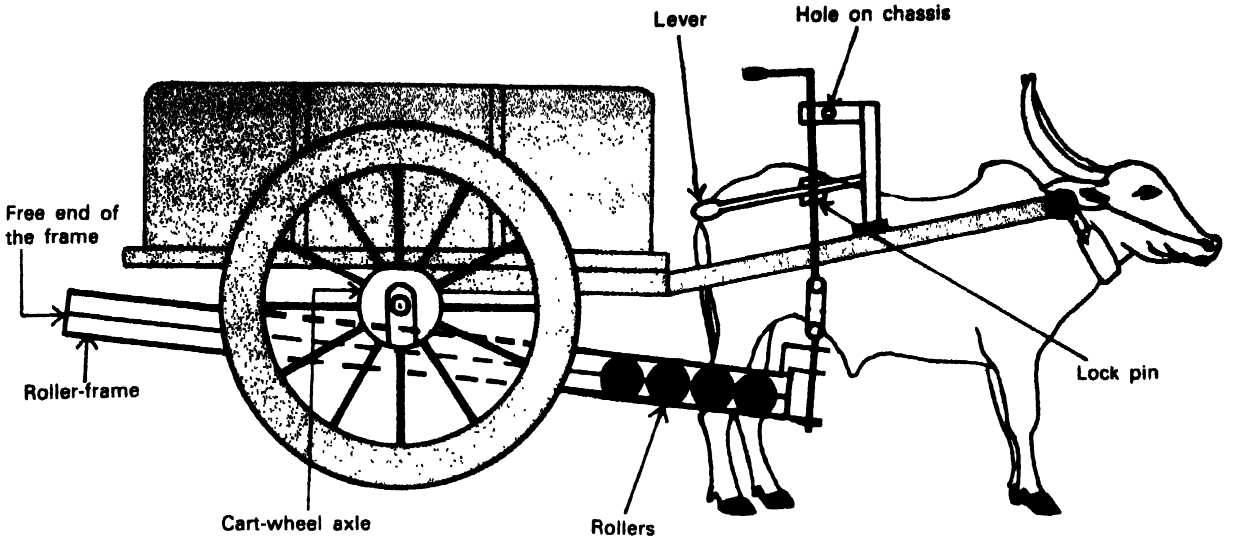
The third alternative introduced in 1976 by Shri Venkataraman of the PSG Institute of Technology incorporates a third wheel in the front of the cart to tackle the problem. Sometimes the third wheel is at the back instead of the front. The paradox of the third wheel is simply that it is most required on uneven terrain where shock loads on the animal are greatest, yet it is precisely here that it literally breaks. On metalled and macadamised surfaces, the cushioning effect of pneumatic tyres takes care of some of the vertical load, but adds to braking friction at the wheels. The problem of the vertical load incident on the animal's neck is greatest on uneven surfaces which account for the bulk of the terrain now traversed by bullock carts.

The large diameter of the wheels is better adapted to coping with uncompacted surfaces, snags and potholes and has therefore to be retained. The rim can in such cases be covered by hard rubber. The vertical load on uneven surfaces remains a crucial and intractable problem. It will have to be tackled through a redesigned yoke or by dispensing with a yoke altogether.

R. A. Parikh's system of rollers is an innovative variation of the idea of the third wheel. It will also, like the other solutions, add to braking friction at the wheels. Its efficiency needs to be tested and established in field trials under varying conditions of terrain, design, freight and draft power. However, there can be no single solution for the different types of carts—for example, low slung and high slung—and animal breeds of varying heights and capacity. Lasting solutions must also find simple variants for the present system of yoking the animals.

N. S. RAMASWAMY

Prof. Ramaswamy is Director, Indian Institute of Management, Bangalore.



Schematic view of roller-device to reduce neckload of bullocks. The rollers can roll from the back end to the front end of the cart and vice versa to balance vertical load and minimise damage to the bullock's neck

This transfers all the vertical push or pull gained by the iron frame (by the combined action of the rolling weight of rollers and the length they travel from the back and to the front end and vice versa) to the cart. The cartman can stop and lock the rollers at any desired position in the frame with a simple device by turning sideways the handle provided in front of him.

The device has been quite successful in the field trials. When installed, it can not only relieve the draught animal's torture, and save him from premature death, but can also increase his load hauling capacity and extend his working years.

R. A. PARIKH

Mr. Parikh is a mechanical engineer from Baroda and has won awards for his inventions of a salt harvester and a cooking gas indicator

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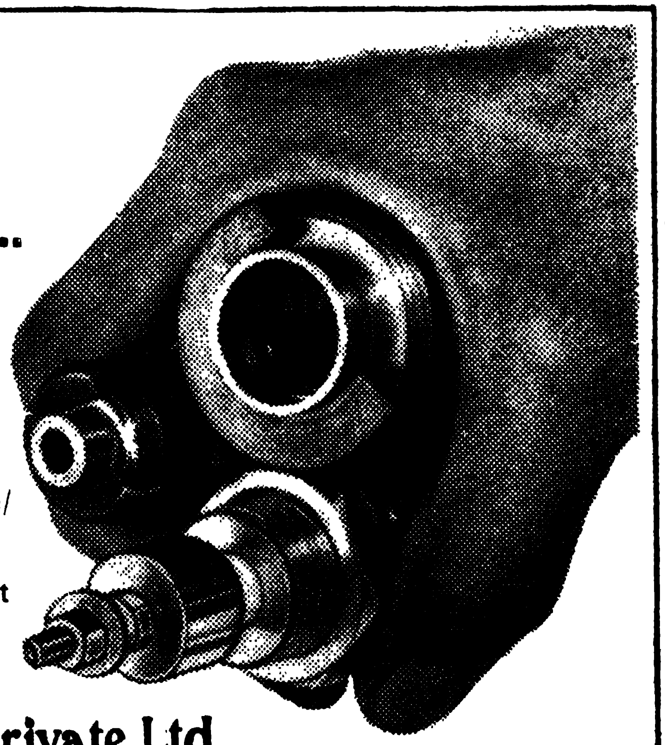

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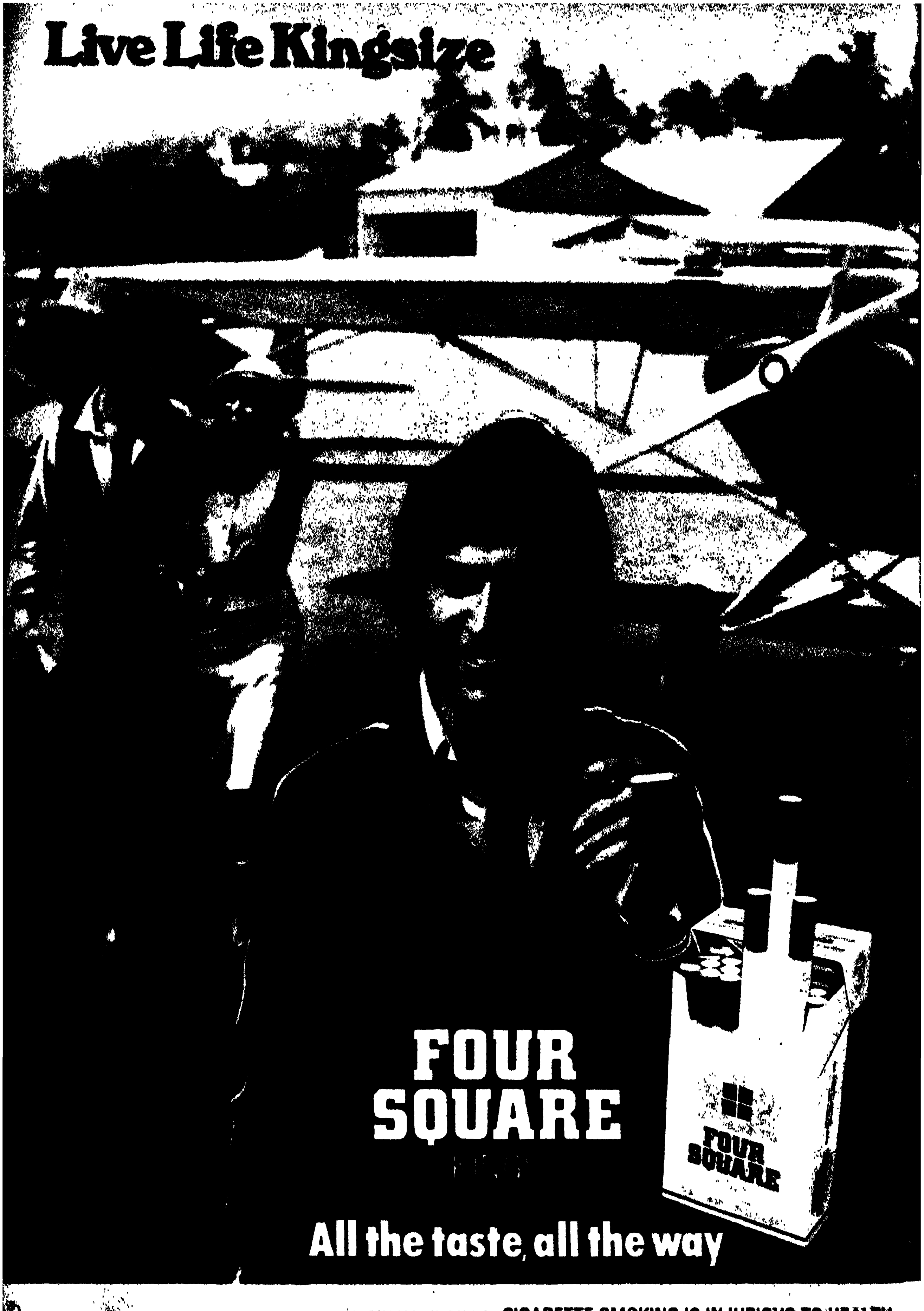

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forests for fuel

Before the forests disappear...

MAN'S involvement with trees has been a love-hate one. He has tended and propagated trees which were obviously useful, trees which yielded fruit, spices, timber and rubber. But he has also been unsparing with the axe. One of the most profligate uses of woodland in recent times has been the conversion of vast areas of the Amazon basin into cattle ranches by multi-national companies for supplying beef hamburgers to the American market.

It is not merely modern man who has been wasteful with woodland. There is evidence that the Harappans laid waste forests to expand their pastures and farmlands, a factor which might have led to floods and hastened the decline of the Indus Valley civilisation. The forests bordering the Scandinavian countries were burnt centuries ago to boil brine for salt; the Mediterranean forests were consumed by the ship-building activities of the ancient Greeks and Romans; and the cedars of the Lebanon went into the temple and mummy-case building trade.

With the coming of the Industrial Revolution, when coal and oil became the dominant fuels, and steel and concrete the prime building materials, wood receded to the background in industrial countries. With the recent oil price crisis, it is once again coming to the fore.

In the developing countries, which in general are also poor in fossil fuels, wood is still an important fuel and will be for many decades to come. For many poor people it takes a whole day to collect fuel for the next day's cooking. Under the head-load system prevailing in many places in India, tribals are allowed to take from the forest whatever they can carry: trees are felled, allowed to rot and then carried away as dead-wood—which is not recorded in forest department statistics. Timber contractors and smugglers take their own toll of the woods. As a result, once densely wooded areas of Rajasthan have been reduced to scrubland. It is the same story in Madhya Pradesh.

Nana Shivalkar

Since tree roots absorb water and bind the soil particles, denuded areas have been experiencing flash-floods.

An estimated 150 million cubic metres of wood are taken out of the moist tropical forests by people in the humid tropics. The dry regions, where biomass production is limited by the low rainfall, are more seriously endangered than the humid tropics or the tropical highlands.

It is true that most countries have forestry departments, but traditionally these have been concerned with conserving the existing forests or regarding them as cornucopia for the furniture and building industry. As recently as last June the Kashmir Forest Development Corporation announced a grandiose plan to extract one crore cubic feet of timber from Kashmir's forests, "as against 90 lakh cubic feet last year."

What is needed to overcome the fuelwood crisis is a new approach to forestry. Forestry has to be taken out of the forest, as Dr. Rangnekar and Dr. Relwani put it (p. 48). Over the last three decades, Vanamahotsava, the Great Forest Festival, has remained a spasmodic ritual confined to the cities, where VIPs are available for the ceremony. Saplings have been planted at street corners and roadsides and then forgotten.

What a massive concern for trees can achieve has been shown in the Philippines where in 1976 a polybagged seedling of Subabul *(Leucaena leucocephala)* was distributed to each school teacher. The teacher planted the seedling and raised it with the assistance of her students. After a year, when seeds were produced, seedlings were grown again for a second year on the school premises. These seedlings were distributed to the students who raised them on the school premises or in their houses. Later, they distributed seedlings to their neighbours for their own planting. At the same time, propaganda was done on radio and TV. In three years, the extension work was so successful that every house now has Subabul trees in its compound.

Equally instructive is the experience of South Korea which has solved its rural fuel problems by a grassroots programme. The rapid industrialisation of the 1960s had drawn more people to the cities and had created glaring disparities in incomes. As part of the 'saumaul' or new community programme, a forestry scheme was launched in 1973 to mobilise villagers to plant public and private lands, to produce mushrooms and valuable leaves and to establish firewood lots to meet local needs. Over the centuries, village level forestry groups had been established in a desultory way. The government now encouraged the setting up of Village Forestry Associations (VFAs) as part of a national non-governmental network headquartered in Seoul. Owners of suitable lands were given the option by the VFA officials either to reforest the area themselves or turn them over to the VFA in return for a tenth of the proceeds. The harvested wood from the woodlots is distributed among the households and any marketable surplus is put into a co-operative fund for further community development projects. The federation of the VFAs expects that the country's rural problems will thus be largely solved in the early 1980s.

Critics of such programmes argue that they have been achieved by regimentation and their success due to the peculiarities of South Korea's culture with its Confucian tradition and emphasis on obedience to authority. Yet the tangible results suggest that regimentation alone could hardly have done the job. For many families which had been obliged to use coal for home heating, the locally grown fuelwood augmented incomes by an average of 15 per cent.

In the Philippines, mass involvement was undoubtedly the main factor making for success, while the fact that none of the islands receives less than 1,000 mm of well-distributed rainfall might also have contributed. Erik Eckholm, the Worldwatch researcher who first drew attention to the fuelwood crisis, suggests that the combination of political will at the top and willingness at the bottom which marked the South Korean success has lessons for other countries with fuelwood shortages.

In China and Indonesia, too, house gardens supply a good deal of the family's fuel and in the former, about 4.5 per cent of the population is believed to be engaged in village forestry.

While social and farm forestry can take care of cooking fuel needs, power generation for industry will require energy plantations (p. 46). In countries like the USA and the Phillippines, the spadework for this is being done. Dr. Gurumurti and Mr. Raturi have worked out the modalities for such power generation (p. 46).

We have nearly 7 million hectares of *usar* land in India, land rendered unfit for agriculture by their salt and alkaline content. Substantial work has been done to identify the tree species which can be raised on such soils (p. 43) but if tree cropping is to be taken up seriously, the economics of plantings, suitable cropping patterns and genetic improvement, as also pest and disease resistance, will all have to be studied. In any fuelwood trial, local species will have to be given priority. Some species recommended for fuelwood planting are hardy and aggressive and when introduced into benign terrain might run wild and become weeds.

Subabul has given a good account of itself in Uruli Kanchan (p. 51) but in other areas, the shoots, seedlings and even the leaves have been nibbled by monkeys and hares. Since the seedlings require individual care, Subabul perhaps will be more suitable for social forestry and farm forestry schemes rather than for large-scale afforestation.

The great attraction of social forestry is that it requires much less expertise than traditional forestry. In Addis Ababa, farmers grow eucalyptus under conditions which make nonsense of scientific silviculture but which work—for them. Preliminary reports from Gujarat are encouraging: farmers there have found eucalyptus cultivation profitable enough to give up conventional crops.

Under the Sixth Five Year Plan, a social forestry scheme will be launched in about 100 selected districts all over the country. This will reinforce the existing social forestry schemes at the State level. The programmes include the "A Tree for Every Child" scheme under which seedlings will be distributed free of cost to the farmers and children. Seedlings supplied to farmers will be those which can supply fuel, timber and fodder, while seedlings supplied to the children will be fruit trees, so that while eating the fruit the children will presumably imbibe tree-consciousness. The success of such programmes will largely depend upon the socio-cultural, economic and religious milieu of the locality and the attitudes of people to change and governmental intervention. They will have to be assessed periodically by experts (p. 53).

Forests are the last great natural resource. Because they are renewable they can outlast the fossil fuels and nuclear energy. We have to come to terms with the jungle. Thanks to a countrywide attack of conscience, Silent Valley, the only remaining bit of tropical rain-forest in India, has received a reprieve. The same kind of consideration should be bestowed on the disappearing forest lands. While official action like the proposed Central legislation to conserve forests and discourage tree-felling is welcome, support should also be given to volunteer groups like Sunderlal Bahuguna's Chipko movement.

PRAVIN KUMAR

Mr. Kumar is on the editorial staff of SCIENCE TODAY

forests for fuel

THE SECOND ENERGY CRISIS

Time is running out for the forests, unless the inroads made into them by fuel-gathering and lumbering are compensated by replanting and village woodlots

THE major concern of most governments at present is to increase and conserve energy supplies. Since energy for rural development has become one of the more crucial issues, firewood is beginning to enter the mainstream of national and international priorities and policies. Now there is new regard for foresters and appreciation of the importance of their skills to a nation's present and to its future. Many government departments other than forestry have suddenly become interested in funding tree-growing—for example, departments of energy, agriculture, rural development, conservation, natural resources, and community services.

All over the world, foresters and even national political leaders are beginning to recognise the need to integrate forestry into rural development in new ways. The World Bank, the world's largest lending institution, in a recent forestry sector policy paper has announced its intention to multiply its support for such activities as village woodlots, farm forestry, and environmental rehabilitation. And in Nairobi, the International Council for Research in Agroforestry has been set up to coordinate and stimulate efficient land-use through combining wood and food production.

Firewood—far from becoming outmoded—has become a recognised source of energy, and demand will increase enormously in the coming decades. Indeed, wood products are likely to continue as the most important universal fuel for rural areas of developing countries.

John Spears of the World Bank calculates that even with optimistic assumptions that wood-conserving stoves, biogas reactors, and solar cookers will be used where available, an additional 20–25 million hectares of trees must be planted by the year 2000. At the present rate of reforestation, that is 10 times more than will be achieved.

Wood can be grown where no fuel was produced before. It is renewable and its production can be sustained. The Indian neem tree, introduced to the Accra Plains of Ghana early this century, has been providing firewood to towns such as Kumasi (and to villages in many West African countries) ever since, and the supply seems to be keeping up with demand as the vigorous and resilient neem is reseeded by bats that eat its fruit.

Wood can be a "self-reliant" fuel that requires little foreign exchange and is independent of the vagaries of international commerce. It does not demand a sophisticated distribution network; indeed, it is the most accessible form of energy for most rural populations in developing countries. It is a familiar fuel whose use requires few extension services. One of the cheapest sources of energy available, it can, if necessary, be used without expensive metal appliances. It is one of few fuels that an individual can produce for himself. Near Mendi in Papua (New Guinea), highland tribesmen plant *Casuarina oligodon* for firewood around community "longhouses" and in abandoned farmland. Although contact with this remote valley was made only in the last 20 years, today it is common to see tribesmen sitting beside the road surrounded by cords of firewood for sale.

D Sharma

Pigeon pea stalks gathered for fuel (Hyderabad)

B. Russell

Car powered by wood gas that in 1979 travelled coast to coast across the United States on about 1,400 kg of wood

Fuelwood is not limited to household use. Large energy plantations are planned or are already under way in the United States and many other countries to fuel machines.

The lumber and paper industries have long used bark and waste to generate steam and electricity. Indeed, eight per cent of Sweden's energy and 15 per cent of Finland's energy is generated from wood; in the United States, in 1974, more energy was generated from wood than from nuclear power. An electric generator designed to consume about 25,000 dry tons of wood fuel each month has recently been installed at the Jari Project in the Brazilian Amazon to power a pulp mill, a saw mill and a township of over 10,000 people.

The Philippines plans to support rural electrification with several wood-fuelled power plants. Early in

1978 it planted an energy forest of *Leucaena leucocephala* which will be used to fuel a 75 megawatt steam power plant. A study that considers hauling distance, plantation and cooling-water requirements, and available government reforestation areas has identified 25 potential energy plantation sites with a total area of approximately 320,000 hectares. If fully planted, these could support 19 wood-fired power plants with an overall generating capacity of 1,425 megawatts. According to the official report, a wood-fired electrical generating plant could not only compete economically with an oil-fired plant, but could also generate an estimated net foreign exchange savings of approximately $ 146 million in the first 10 years of operation.

Firewood production can be good for economic development in rural areas. Growing trees for firewood can be successfully combined with the production of posts, poles, and timber. The production and sale of wood to nearby urban centres can provide many jobs and much cash income for rural areas. It has been estimated that some 6,000 families are involved in supplying wood and charcoal to the city of Maputo in Mozambique, for example. Few other energy sources can provide and maintain such high employment.

Firewood plantations

It has been estimated that at least 75 per cent of tropical land is inherently unsuited to sustained conventional agriculture, but 35 per cent of the population of the tropics lives on this land. About half of it will not support vegetation of any kind. The best use of the remainder is tree cultivation (or the simultaneous or sequential cultivation of trees with annual crops or with the pasturing of animals). Virtually everywhere, villages have unused or misused areas on which woodlots can be planted.

But there is little modern experience with growing trees explicitly for firewood, even by most foresters. Fuel production has long been considered the lowest use of wood, and foresters have traditionally cultivated trees primarily for other purposes, such as timber and pulpwood. For these products, the species they choose to grow are not those that would be grown purely for fuel.

Firewood plantings can use species with short boles, crooked trunks, or wood that warps or splits as it dries. These features are not as detrimental to fuelwood use as to timber production. Nor is stem size. In simple cookstoves, for example, branches as small as one or two centimetres in diameter may be ideal. Thus, a shrub may prove satisfactory for village fuelwood silviculture if it grows fast and produces a dense wood that burns with intense heat. In practice, fuelwood may come both as a primary crop from fuelwood forests and as a secondary crop from timber forests.

For 25 years, steadily expanding fuelwood plantations of *Calliandra*, a small Central American tree that was imported as a shade and ornamental tree have been established in Java, until they now cover more than 30,000 hectares there. The wood, too small for lumber, is dense, burns well, and is ideally sized for domestic cooking. It is also useful for fuelling brick, tile, and lime kilns and for copra and tobacco driers. Indonesian villagers now cultivate it widely on their own land, often intercropping with food crops. Today the villagers make good living selling the firewood, earning more from it than from their food crops.

Another example of shrubs grown successfully for firewood is found in South Korea. Known as "miracle plants", the leguminous bushes *Lespedeza bicolor* and *L. thunbergii* rapidly cover bare ground, and their long, shallow roots bind and hold down soil. Prolific root nodules provide nitrogen, and their protein-rich foliage is fed to livestock. Foresters plant *Lespedeza* species around pine seedlings to protect the soil, to provide plant nutrients and to produce forage and firewood until the forest is established. The dense wood of the small stems is eagerly sought for cooking fuel, and it is a well-established Korean practice to plant *Lespedeza* species along ridges as a firewood crop.

Nana Shivalkar

Other benefits from woodlots

In addition to fuel, woodlots in and around villages and cities can provide stable and pleasant surroundings. They also reduce wind erosion, beneficially influence local temperature and humidity, and in many cases replenish and re-distribute essential soil nutrients.

A covering of vegetation slows rainfall runoff, which generally allows for greater groundwater recharge and so helps maintain year-round stream flow. Thus it decreases the likelihood of floods and the build-up of silt in reservoirs, thereby increasing the capacity and life of hydroelectric and irrigation facilities.

Most efforts to combat flooding and siltation (as well as snowslides and landslides) have entailed engineering measures—dams, embankments and dredging. But these relate to symptoms, not causes. Reforesting denuded areas is a preventive measure that decreases the severity of flooding and decreases the load of sediment entering waterways. For decades floods, drought and famine were recurring calamities of Fukien Province in China, but in the five years since forests were re-established in the hills and watersheds, the inhabitants have lived free from all three.

Indiscriminate firewood collection is currently one of the principal destroyers of native forests. Intensively cultivated woodlots on accessible sites can help relieve this pressure on natural forests by supplying a large share of the needed firewood more conveniently.

Woody plants can provide more than fuel calories. They can also be sources of: vegetable oil and fruits and nuts for food; edible leaves and shoots for sauces, curries, salads, and beverages; honey; forage for livestock and silkworms; green manure for fertilizing soil; tanbark for the tannin used in leather making; medicines and pharmaceuticals; extractives such as resins, rubber, gums and dyes; timber, lumber, posts, poles, and pulp for paper, cardboard, and construction boards; and shade for pastures or plantation crops such as coffee and cacao.

Some of these uses are inimical to

fuel production, but they give the tree owner more flexibility; he has the option of using some specimens perhaps for forage, while keeping others for fuel.

Fuelwood management

Today, international aid agencies and foresters in the Third World are receptive to new notions about the objectives and practices of forestry. In essence, they recognise the modern necessity of taking forestry outside the forests—of involving people throughout the countryside in growing trees to meet their own requirements as well as to protect the land off which they and their livestock live.

Firewood production is less dependent on silvicultural expertise than saw-timber is, and therefore can be done by non-professionals who learn the basic techniques for their own use. However, though the cultivation of firewood species does not demand continuous professional supervision, a forest service may be needed to provide seed or planting stock and advice for getting the trees established.

Trees for firewood can be planted in "non-forest" areas: along roadsides, in shelterbelts, on farms, on unused land, and in schoolyards, cemeteries, churchyards, market squares, parks and home gardens. Fuelwood trees can be cultivated in small woodlots, even as individual specimens around a house or village. In some areas, such as Java and the People's Republic of China, home gardens already supply a good share of family firewood needs.

Rural areas can probably supply their own fuelwood from small, local plantings, but urban areas can best be supplied from concentrated large plantations, strategically located and possibly government administered.

Firewood plantations can be self-renewing. They are usually managed on rotations of about 10 years (much less in some moist tropical regions). The timing varies with the quality of the soil, species used, temperature, moisture available, and intensity of cultivation. Rotations of less than five years seem feasible in many areas, especially for those species that regenerate by sprouts (coppice).

Characteristics of fuelwood species

Trees most likely to prove useful for fuelwood plantations are those termed "pioneers", which in nature colonise deforested areas. These withstand degraded soils, exposure to wind, and drought. Many are rapid-growing legumes that fix atmospheric nitrogen. The very nature of a pioneer species endows it with adaptability, aggressiveness and hardiness on hostile terrain. The most promising species are often the last natives to survive repeated grazing, cutting, fire and soil degradation. These are usually well known, available nearby, obviously adapted, and tough. Some of these species may not require nursery production and laborious transplanting. Some pioneer species can be seeded directly on site; large stands of *Leucaena leucocephala* and *Sesbania grandiflora* have even been established in South-east Asia merely by scattering seed from the air.

At the same time, the vigour and adaptability of some of these species make them potential weeds. The ability to coppice or grow rapidly from root suckers is exceptionally important in a firewood species. The stumps of coppicing plants do not die; instead, dormant or adventitious buds regenerate new shoots. This

Nana Shivalkar

Acacia tortilis from the Negev Desert, Israel. The 'umbrella thorn' supplies fuel to much of arid and semi-arid Africa and the Middle East. It is a drought-resistant species that can be established in a wide array of habitats under extremely arid conditions

allows repeated harvest without the cost and effort of replanting seedlings each time. Moreover the living roots continue to bind the soil, and a canopy of new foliage quickly develops to shield the soil surface from rain and wind and helps suppress weeds. Coppice sprouts usually grow vigorously because they are served by roots big enough to feed the former tree.

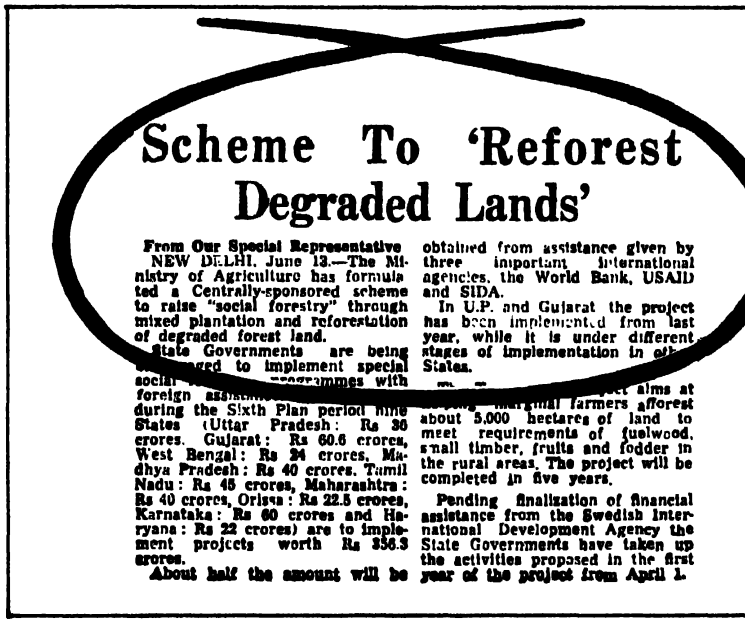
Most woods burn, but their relative value as fuel is measured by certain characteristics. Density is the most general gauge of a wood's burning quality. The heavier the wood (when dry), the greater its calorific value. The heat given off is enhanced (by about 20 per cent) by the resins found in conifer woods and by the oils and gums sometimes found in hardwoods. Green wood has a lower heating value than dry wood because energy is used in evaporating the moisture. The loss may reach 20 per cent which represents the wastage of one growing year in every five. Air-drying the wood yields more calories per unit of time than does tree growth in the forest. Air drying is thus a critical firewood conservation measure.

Some woods burn well even when green, a particularly important advantage where fuel is so urgently needed that the users are unlikely to take the time to dry their firewood. Rotted wood gives less heat than sound wood, so that a species's natural durability and resistance to fungal decay may be important. Some woods are poor fuels for use in unsophisticated stoves because they spark excessively or because their smoke is odorous, toxic or irritating.

Planting fuelwood on a large scale demands social and political commitment. Decision makers in many countries, including Nepal, South Korea, the Philippines, and the Sahelian countries, are already funding national tree-growing programmes, but elsewhere the impending crisis is generally not attracting the necessary financial commitment. This neglect is likely to disrupt energy supplies and lead to severe hardship in rural areas. As the pressures for fuel increase, it may lead to civil unrest and the devastation of new plantations.

What needs to be done

To alleviate the growing shortage of wood fuel is one of mankind's major challenges. To this end, firewood research is vital, requiring the combined efforts of government, industry, landowners, villagers, researchers, philanthropic institutions and development-assistance agencies. Some activities to be undertaken (sequentially or concurrently) include:



Scheme To 'Reforest Degraded Lands'

From Our Special Representative

NEW DELHI, June 13.—The Ministry of Agriculture has formulated a Centrally-sponsored scheme to raise "social forestry" through mixed plantation and reforestation of degraded forest land.

State Governments are being [illegible]aged to implement special social [illegible] [illegible]ogrammes with foreign ass[illegible] during the Sixth Plan period nine States (Uttar Pradesh: Rs 30 crores, Gujarat: Rs 60.6 crores, West Bengal: Rs 24 crores, Madhya Pradesh: Rs 40 crores, Tamil Nadu: Rs 45 crores, Maharashtra: Rs 40 crores, Orissa: Rs 22.5 crores, Karnataka: Rs 60 crores and Haryana: Rs 22 crores) are to implement projects worth Rs 356.3 crores.

About half the amount will be obtained from assistance given by three important international agencies, the World Bank, USAID and SIDA.

In U.P. and Gujarat the project has been implemented from last year, while it is under different stages of implementation in oth[illegible] States.

[illegible] aims at [illegible] marginal farmers afforest about 5,000 hectares of land to meet requirements of fuelwood, small timber, fruits and fodder in the rural areas. The project will be completed in five years.

Pending finalization of financial assistance from the Swedish International Development Agency the State Governments have taken up the activities proposed in the first year of the project from April 1.

- Searching out and reducing the wasteful use of available fuel. For example:

1. Ensuring that existing wood resources are harvested and used without waste;

- Testing and developing fuel-efficient stoves, particularly ones that villagers can make themselves; and
- Instituting policies and programmes that encourage the use of alternative energy sources such as biogas and solar heat.

2. Conserving existing fuelwood sources. For example: controlling harvesting intensity to preserve forest productivity.
3. Identifying available production areas such as those in existing forests, wastelands and farmlands.
4. Identifying the tree species found locally, noting especially the species traditionally preferred for fuel.
5. Testing tree growth in all the available production areas. In all trials of exotic species, local species must be included for comparison. Characteristics of the trees that should be assessed include growth rates by volume and dry weight (of stem and branchwood), wood and chemical properties and resistance to pests. The importance of selecting and using the best seed source within a species cannot be overemphasised.

For species that show promise, adaptability trials should be set up to determine the responses of various species to different soils, growing conditions, altitudes, latitudes, temperatures, moisture conditions and pests. This will indicate the relative advantages and limitations of each and will provide the technical backup for pilot-sized fuelwood plantations than can serve as demonstration plots. It will also enable researchers and officials to become familiar with the species tested. These trials might also provide the germplasm to start local woodlots and firewood plantations.

Comparison of experiences from such pilot plantations will provide the foundation for decisions establishing and utilising firewood plantations and allow predictions of economic success.

Most of the species selected are likely to be grown mainly in woodlots and backyards or planted to double as living fences, or shade trees in pastures, or in plantations of coffee, cacao, or other crops. Testing should, therefore, be done over a range of such conditions.

Excerpted by permission from *Firewood Crops*, a report of the Board on Science and Technology for International Development, National Academy of Sciences, USA.

forests for fuel

Planting for Energy

R. N. Kaul
K. Gurumurti

The knowhow is now available for running mini power-stations fed by fuelwood and each catering to a small group of villages

Pratap Singh

In many parts of the counry, tribals are permitted to carry away a headload of fuel from the forest

BRANDISHING placards reading "Trees for the people" and "Daylong journey for fuel—relieve us of backbreaking labour", 1,000 Kenyans carried symbolised bundles of firewood and laid them at the feet of delegates attending the UN Conference on New and Renewable Sources of Energy at Nairobi last August. The delegates were obliged to suspend their consideration of sophisticated energy sources like wind, wave and solar power and focus attention on "the second energy crisis"—the fuelwood crisis. For, in the Third World, which mostly lacks hydrocarbon fuels of its own, and finds imported fuel prohibitively expensive, fuelwood is by far the most important fuel.

In India, the rural poor, particularly in remote villages where LPG, kerosene and coal are hard to come by, are mostly dependent on fuelwood felled from the forests. Indiscriminate felling, however, has led to flash-floods, soil erosion and silting of dams, which were meant to check floods and provide electricity and irrigation water. Moreover, the demand for fuelwood is fast outstripping the resources of existing forests and new growth. In fact, by the turn of the century — as things are going at present — India may have enough food but not enough fuel to cook it.

We have to turn to the renewable sources of energy, to biomass (see SCIENCE TODAY, August 1981, p. 19). In particular, we have to draw more upon the solar energy stored by plants and trees in their tissues. A tree that coppices well (gives out shoots) can go on yielding fuelwood.

Wood, charcoal and agricultural and animal residues have remained the predominant fuels. Alternative sources of energy are needed, especially for our villages. Some of the alternatives are: (a) intensifying the productivity of existing fuelwood resources; (b) creating new fuelwood resources; (c) organising the distribution of fuelwood; (d) improving conversion technologies; (e) improving wood-burning devices; and (f) harnessing other alternative sources for supplementing existing energy sources.

The quickest solution is fuelwood plantations which, when properly managed, are renewable. The present per capita fuelwood consumption is 0.6 tonnes. With a population of 684 million (1981 census) the present requirement of fuelwood would be of the order of 410 million tonnes per annum. According to the National Commission on Agriculture (NCA), 1972, the fuelwood production in the country is expected to fall short of the requirement by 100 million m^3 in 1990.

The concept of fuelwood plantations is simple, its implementation is not. Fuelwood plantations are a means of producing fuel from plant material in a practical and economical fashion by carefully choosing the appropriate species, the planting density and the harvest schedule for each site. The plantation is operated so as to minimise the production cost of the material required.

Two major approaches are involved in fuelwood plantations: (1) decentralised social forestry fuelwood systems which should be raised and maintained by the local community, (2) commercial fuelwood farming or the systematic and sustained production of fuelwood on a large scale and intensively by State Forest Departments. Fuelwood plantations could be established cost effectively under both these approaches, and scientific know-how for producing fuelwood by this means is available.

Choice of species

The primary emphasis should be on species suitable for growing fuelwood for individual family needs. However, species useful for fuelling small industrial factories, electric generators, and crop driers should also be considered. Sometimes even woody shrubs may meet the many requirements of small villages. While selecting the species, special consideration must be given to characters such as rapid growth, ability to coppice, high calorific value combined with better burning quality, capacity to grow under a wide range of environments, soil types, rainfall regimes and terrain and nitrogen-fixing ability. Simultaneously, we should also look for multi-use plants that adapt to different sites, establish easily, require little care and those which are subject to least biological disruption by goats and wild animals.

In any trial of fuelwood plantations the local species should always be given top priority. For a number of these species, data on yield, ability to raise plants from stem cuttings are already available at the Forest Research Institute and Colleges, Dehra Dun. For example, studies on spac-

Eucalyptus plantation along a railway line

ing (1.83, 2.74 and 3.66 m^2) of *Casuarina equisetifolia*—a well-known firewood species—carried out in Puri, Orissa revealed that the stands attained top height of 18 to 21 m at 19 years' age. Maximum volume production is attained at a close spacing of 1.83 m. The maximum mean annual increment attainable is about 6 m^3 per ha at seven years' age. Similarly, Eucalyptus hybrid spacing (1.0, 1.5, 2.0 and 2.5 m^2) trials at Warangal Research Range, Kothagudem Division (Andhra Pradesh) showed that at six years' age the highest mean yield of 92.70 m^3 which was 83.5 per cent more than the yield under 2.5 m^2 spacing. In another experiment, Eucalyptus hybrid at five years' age gave the highest mean yield of 57.44 m^3 per ha when raised at a spacing of 1 m^2, which was 77.1 per cent higher than the mean yield obtained under 2.5 m^2 spacing.

Nana Shivalkar

A number of plants like *Acacia nilotica* spp. *indica*, *A. tortilis*, *Albizia lebbek*, *Cassia siamea*, *Dalbergia sissoo*, *Eucalyptus*, *Leucaena leucocephala*, *Prosopis juliflora*, and *Sesbania grandiflora* can produce very high yields when plantings are done at the rate of 10,000 plants per ha. Work carried out at the AMM Murugappa Chettiar Research Centre, Madras, has shown that it is possible to obtain 200–250 tonnes of dry wood per ha using *Casuarina equisetifolia* in four-year rotations with 10,000 plants per ha. Most of these nitrogen-fixing tree species would also improve the soil nitrogen through their root nodules.

Land for fuelwood plantations

As already mentioned, the requirement of fuelwood alone is estimated to be 256 million m^3 and 300 million m^3 by 1980 and 1990, respectively. The aggregate raw-material requirement of wood (excluding bamboos for industrial and non-industrial uses) is estimated to be 35.2 and 64.5 million m^3 in 1985 and 2000, respectively, under assumption of high income growth. The demand for wood, both for industrial uses and fuel is rising. But the productivity of our forests is low, and while the industrial demands may be met by the existing forest resources, land for fuelwood plantations will have to be mobilised from other land resources.

The national forest policy of India advocates that 33 per cent of total land area should be under forest. However, of a total of 328 million ha, only 22 per cent is reported to be under forest. There is thus an additional 10 per cent (about 32 million ha) of land which could be brought under forest, which would be exclusively for fuelwood plantations.

Based on the statistics provided by the National Commission on Agriculture (1976) 2.7 million ha of land are available on the boundaries of farms. The area under shifting cultivation in the North-eastern region, Orissa and Andhra Pradesh is around 3 million ha. The total land available along roadsides, canal banks and railway lines has been conservatively estimated to be about 0.6 million hectares. Over 13 per cent of the total area (43.6 million ha) has been classified as wasteland which is neither under forestry nor under agriculture. Assuming 50 per cent of this wasteland to be of no value, about 20 million ha could be brought under fuelwood plantations. Thus, a total of 25 million ha land could be brought under fuelwood plantations, which would raise the forest area of the country to about 30 per cent of the total.

People's participation

Programmes to raise fuelwood plantations require people's participation. The Central or State Government can provide plans, money and advice, but unless people are made to realise the importance of raising such plantations, specially in community lands to which they have traditionally free access for grazing and wood gathering, they are apt to view the project with suspicion. The various village organisations need, therefore, to be mobilised to ensure the people's participation in successful implementation of these programmes.

Commercial energy farming

Rural electrification is costly because it involves bringing transmission lines from the main grid to sparsely populated villages scattered over large areas of land. Fuelwood-powered thermal stations, each of which serves a group of villages, would be an economic source of power to villages, providing energy for agriculture as well as rural industries.

It has been estimated by Gurumurti and Raturi that, using 18 tonnes of air-dry wood it is possible to generate 20,000 kilowatt hours of electricity daily, for a group of 15 villages. The land required for generating that much electricity would be 145 ha. They have worked out the design and management practices for continuous production of 20,000 kilowatt hours (kWh) daily from the same area and have also suggested methods to recycle the minerals to prevent deterioration of site quality of energy plantations (see p. 46).

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	May 1981
[illegible]	[illegible]	3.78	[illegible]	4.00	4.16	[illegible]
[illegible]	[illegible]	[illegible]	0.35	0.58	0.79	[illegible]
[illegible]	[illegible]	10.10	3.77	5.47	[illegible]	6.10
[illegible]	[illegible]	[illegible]	2.11	2.76	5.19	0.97
[illegible]	[illegible]	[illegible]	2.28	3.78	3.07	3.44
[illegible]	[illegible]	[illegible]	12.52	18.59	[illegible]	17.73

[illegible] November 1979.

In our country there are 5,67,000 villages. Assuming one unit of fuelwood power generating capacity to be established for every 15 villages, a total of 37,800 power generating units on decentralised basis would be required. At the rate of 145 ha of land for each power generating unit, the total area required for the whole country would be 37,800 × 145 or 54,81,000, say 5.5 million ha of land. This is a mere 12.6 per cent of the total wasteland (43.6 million hectares). In fact, it would be less, for quite a few villages are covered under hydel power generation. The only problem is that for every 15 villages, 145 ha of land should be made available locally, not necessarily in a single block but in groups situated around the villages. Though the task is a difficult one, nevertheless it is worth a trial because of the enormous employment potentials, apart from making sustained power available for agriculture and industry.

The Forest Research Institute, Dehra Dun, in co-operation with the Gujarat Forest Department, has established a 25 ha plot of fuelwood plantations at Indroda near Ahmedabad. In 1979, nine fast-growing species at a spacing of 1 m^2 were planted under non-irrigated conditions. The yield data of these species at 12-month and 18-month intervals have been worked out (Table 1). It is proposed to assess comparatively the performance of various fast-growing species in the given tract. The rotation period is fixed for four years. The data from this pilot project, which is well under way, would enable a feasibility study for establishing village fuelwood plantations as well as power generation facility

Village forestry programme

FUELWOOD plantations can be raised on land along roadsides, canals, river banks, common village areas, field boundaries, hill slopes and degraded lands abandoned due to faulty cultivation. The village forestry programme in Gujarat has demonstrated the cost effectiveness of this method. This programme was started in *gauchar* lands of 100 villages in 1974 involving a total area of 400 ha. Each village *Panchayat* gave 4 ha of land for the purpose. The areas were fenced and planted (5 × 5 m) with species like *Acacia nilotica* spp. *indica*, *Albizzia lebbek*, *Azadirachta indica*, *Casuarina equisetifolia*, *Dalbergia sissoo*, *Eucalyptus* hybrid, *Peltoforum ferruginum Pongamia glabra*, *Sesbania grandiflora*, etc. No extra efforts to raise grass were necessary, as grasses came up well with fencing. The villagers are allowed to cut grass free or sell through *Panchayats*. The cost-benefit analysis is as follows:

Capital Expenditure	*Per ha*
Cost of land	Nil
Cost of formation	Rs. 400
Cost of supervision charges, etc	Rs. 400
Total	Rs. 800
The investment would stagnate for 15 years; compound interest at 6.5 per cent will amount to	Rs.1,300
Grand total	Rs.2,100

Returns. Initially the output will be grass and later, firewood. Assuming that 50 per cent of the grass is grazed by cattle, the surplus yield of grass is estimated at 1,000 kg per ha per annum. Standing grass sells at Rs. 40 per 500 kg, which will fetch Rs. 80 per ha per annum or Rs. 1,200 for 15 years. The interest earned on the recurrent annual revenue at the rate of 10 per cent simple interest for half the period would be (Rs. 1,200 + Rs. 900) or Rs. 2,100. Thus, the income from grass alone would balance the initially invested capital.

Assuming that only 50 per cent of 400 trees are available for felling in 15 years the cost of timber at a very meagre price of Rs. 25 per tree works out to Rs. 5,000 which is a net profit. Here the output in terms of environmental improvement has not been calculated, which will be substantial for *gauchar* land. The above analysis will work successfully, provided *Panchayats* take the full responsibility for protection of the area. Similarly, the work carried out by the Haryana Forest Department has shown that raising fuelwood trees in agricultural lands along with the main crops (approximately 350 saplings planted around the outer periphery of one ha) gives a gross income of Rs. 1,875 per ha per year.

In UP the social forestry project covering 40 districts is already in operation. Under this project, multipurpose tree plantation in presently unproductive and unused land including community lands is being carried out to provide fuel, fodder, timber and raw material for cottage industries and to provide employment to the rural poor, the members of the community (Gaon Sabha) are permitted to collect free of charge *mahua* flowers, dead wood or fallen twigs, fodder leaves and grasses.

R. N. K.
K. G.

Nana Shivakar

using wood-fuelled thermal generators.

Kaul and co-workers have established *Acacia tortilis* plantations over 800 ha of shifting sand dunes in the arid regions of Rajasthan. This plant which coppices well and grows twice as fast as indigenous acacias and withstands arid conditions better than *A. nilotica* spp. *indica*, *A. senegal* and other indigenous species, not only serves as fuelwood but is also excellent for soil stabilisation.

If the fuelwood needs of our villages are to be satisfied without continuing and increased environmental degradation, ways and means must be found to grow fuelwood on a sustainable basis, in addition to harnessing other renewable sources of energy, especially solar and wind power and biogas.

Mr. Kaul (53) is Director of Forestry Research, Forest Research Institute and Colleges, Dehra Dun. He is an Assoc. IARI (Agron.) of the Indian Agricultural Research Institute, New Delhi and AIFC of the Indian Forest College, Dehra Dun. He was a UNESCO fellow from 1962-63 at the CSIRO, Australia, the University of California, Berkeley and the Forest Research Institute, Israel. His research career has been in the areas of Silviculture and Environmental Forestry, particularly afforestation of difficult sites. He was UNESCO Project Manager from 1969-76 at the Institute for Applied Research in Natural Resources, Baghdad, Iraq. He has served as Consultant for UNESCO, UNU and UNEP. He was for several years Secretary of the Arid Zone Association of India and Editor-in-Chief of *Annals of Arid Zone*.

Dr. Gurumurti (37) is Senior Research Officer and Officer-in-charge of the Plant Physiology Branch at the Forest Research Institute; Dehra Dun. After taking his Ph D from the Gujarat University, Ahmedabad, he worked with the late Prof J. J. Chinoy, the eminent plant physiologist. Dr. Gurumurti's research interests have been vegetative propagation, radiation biology, physiology of seed germination and flowering. He is a member of the Governing Council of Tree Physiologists.

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forests for fuel

Blueprint for Energy Plantations

K. Gurumurti

D. P. Raturi

MOST people think of a power station as something that gobbles up tonnes of coal daily and transmits power to a city of millions or to an area several square millions in extent. But bigness is not all. It is possible to have mini-power stations serving a group of 10 to 15 villages and using renewable sources of energy like fuelwood. The land requirements for raising the fuelwood trees will be modest, because the power requirement will be of the order of a few kilowatts rather than megawatts.

In the Philippines and Hawaii, companies are planting *Leucaena* (Subabul) as a fuel for their power plants, and next year, the national electrification company of the Philippines plans to establish 12,000 hectares of the tree to power a three-megawatt generating facility. A Japanese company in the same country is planting 5,000 hectares of *Leucaena* for conversion to charcoal to fuel a steel foundry.

Unit power generation structures

For power generation on a decentralised basis, using energy plantations, it is necessary to estimate the size of the unit group of villages for which one power generation structure has to be created. Let us assume, a unit consists of 3,000 families distributed over 10 to 15 villages. The power requirement per family per day for lighting and domestic work is about 2 kilowatt hours (kWh). Thus, the total requirement for lighting and domestic work alone would be 6,000 kWh per day. Approximately, an additional 14,000 kWh per day would be required for energising the water-pumps for agriculture and for small-scale industries situated in this group of villages. Thus, a power-generating plant should be capable of generating 20,000 kWh per day for a group of 10 to 15 villages.

How much wood is required?

Air-dry wood having 10 to 15 per cent moisture has a calorific value of not less than 3,700 k. cal per kilogram. Therefore, one ton of wood has a calorific value of 1 × 1,000 × 3,700 = 37×10^5 k. cal. Wood-fuel thermal generators have a conversion efficiency of about 35 per cent. Even assuming a 30 per cent efficiency of conversion, this works out to $0.3 \times 37 \times 10^5$ or 11.1×10^5 k. cal per ton of wood. Now, one k. cal is equal to 1.163×10^{-3} kWh. Therefore, 11.1×10^5 k. cal = 1,290 kWh.. Assuming the power plant works at 85 per cent overall efficiency (the transmission losses are expected to be low in a decentralised power generation system) one tonne of wood can be converted into 1,290 × 0.85 = 1,100 kWh. Therefore, to generate 20,000 kWh of electricity per day, for our unit group, about 18 tonnes of air-dry wood would be required daily.

Choice of species

The choice of species is vital in the success of energy plantations. There are two basic requirements for a species to be used for energy plantations, namely, its suitability to the site and fast growth—so that it can be harvested on a short rotation of not more than four years, if not earlier. The other requirements of the species would include its ability to germinate quickly, to propagate from branch cuttings quickly and to re-sprout vigorously (coppicing ability) when the main stem is harvested. Data on various species of trees presently used as fuel in different zones of our country, such as yield and ability to propagate from stem cuttings, reproductive capacity are available; these data can serve as pointers for selecting suitable species. In no case, however, has data been obtained for energy plantations.

C. V. Seshadri, C. Venkataramani and V. Vasant of the A. M. M. Murugappa Chettiar Research Centre, Madras, have shown that *Casuarina equisetifolia* plants are capable of yielding up to 250 tonnes of dry wood per hectare in four years when 10,000 plants are planted in one hectare. In Dandeli, Karnataka, yields as high as 75 tonnes of stalk per hectare per year (air-dry with 10 per cent moisture) have been obtained with *Sesbania sesbun* raised at 30 cm × 30 cm spacing under irrigated conditions. A number of leguminous plants like *Leucaena leucocephala* (Ipil-Ipil or Subabul) (see article on p. 51), *Sesbania grandiflora* (commonly known as *Basna* in Hindi and *Agathi* in Tamil) are capable of producing very high yields. Eucalyptus trees with modified silvicultural practices are also a good choice for energy plantations because they grow rapidly and re-sprout vigorously from cut stumps after harvest. The fast-growing leguminous plants are ideal, for they fix atmospheric nitrogen by means of

Village woodlot on community land

their root nodules, thus improving soil fertility.

Design and operation

As already estimated, 18 tonnes of air-dry wood would be required every day to generate 20,000 kWh of electricity daily for a group of 10 to 15 villages, consisting of a total of 3,000 families. Hence, the wood requirement for the whole year would be 18 × 365 or 6,570 tonnes.

The seasonal energy requirements for different activities like irrigation and small-scale industries are different. Thus, in hot summer conditions the energy required for pumping water may be high and during rainy seasons it may be low. So, depending on the energy requirement, it may be necessary to burn more or less wood than the average of 18 tonnes per day. Hence, sufficient stock of wood should be available for power generation. Further, plantation operations can only be successfully carried out during certain seasons like the monsoon. Also, after harvest, sufficient time is required to prepare the plots for subsequent rotation of planting. It is also necessary to define a minimum area from which the required biomass would be produced for uninterrupted power generation. Taking all these aspects into account, the following design and operation of energy plantation is proposed.

A minimum area of 145 hectares would be necessary. Of this, 137.5 hectares would be divided into 5 blocks of 27.5 hectares each and the remaining 7.5 hectares would be occupied by a network of road surfaces inside the plantations for mobility of harvesting and transporting equipment. Storage facility for harvested wood would also be constructed within this area. In the first year, from June to September, the first block of 27.5 hectares would be planted with species like *Casuarina* or *Sesbania* or *Eucalyptus* or *Populus*, depending upon the region. All these plants are capable of yielding 250 tonnes of dry wood per hectare in four years. Planting would be done at the rate of 15,000 plants per hectare. Assuming a mortality rate of 33 per cent, 10,000 plants per hectare would survive, giving the required yield.

Likewise, the second, third, fourth and fifth blocks of 27.5 hectares each would be planted in successive years. When the plantings are completed in the fifth block, the first block of 27.5 hectares would be four years old and ready for harvest. The wood available in this block would be (250 × 27.5) or 6,875 tonnes, which could be harvested and stored by the end of the fifth year. The wood requirement for a whole year, as worked out above, is 6,570 tonnes. So, from the beginning of the sixth year, electricity generation can start using this wood fuel. After the harvest of the first block, sufficient time would also be available for preparation of this block for the ensuing planting season. By the end of the next year, the second block would have put in four years of growth, which would be harvested and used for power generation in the subsequent year.

Thus, from the time the energy plantation operation begins in the first block, there would be a lag of five years before power generation can actually start. After this, however, the cycle of planting and harvesting would continue regularly, making it possible to obtain 6,875 tonnes of wood every year from a 27.5 hectare plot in a cyclic manner. This management technique also allows sufficient time for harvesting and subsequent preparation of plots for planting without causing any time lag. In this method it is also possible to generate electricity during different seasons as required.

The ash from the fuel-using facility would be transported back to the plantation and spread over the soil. It would thus serve as a fertiliser. The use of fast-growing leguminous plants would further improve the nitrogen content of the soil.

Power generation plants are presently designed for large-scale power generation. However, the scaled-down version of these units with suitable modifications could be easily installed, which may use 18 tonnes of wood at 30 per cent efficiency for the generation of 20,000 kilowatt hours of electricity daily. A recent and most exciting development in this area is the invention of the world's first commercial fluidised-bed combustion boiler by Michael Pope, a 55-year-old consulting engineer of New York city. This small experimental power plant is undergoing trials in Rivesvill (Virginia) in the USA. According to Amory B. Lovins, a British physicist and energy planner, this fluidised-bed system is capable of burning any combustible material The scaled-down version of this system can function as a tiny power house. Lovins further suggests that this system could be modified to recover combustion heat with an efficiency of 80 per cent.

The use of fast-growing leguminous plants like *Sesbania* in these energy plantations has further advantages. The leaves of these plants have over 25 per cent crude protein. Therefore, the proteins from the leaves of these energy plantations can be extracted, processed suitably and marketed, preferably in the villages.

Technologically, these energy plantations use only renewable resources for harnessing energy in usable forms. Such energy plantations, apart from mitigating the energy crisis, would create many jobs for the local population. Ecologically and sociologically, they are much sounder investments. Afforestation and harvesting in a systematic manner will lead to long-term benefits by way of soil and moisture conservation. Energy plantations, thus, have a definite edge over other energy sources in a decentralised, rural-based economy where capital investment per work place needs to be low and land utilisation for traditional skills needs to be high.

Mr. Raturi is Research Assistant at the Forest Research Institute and Colleges, Dehra Dun, and works on plant introduction and energy plantations.

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SOCIAL FORESTRY – the second Green Revolution

L. L. Relwani
D. V. Rangnekar

In the new forestry—Social Forestry—not merely foresters and the governmental machinery, but the entire people will also have to be involved

CROWDS of men, women and children bearing axes and converging upon a Reserve Forest and hacking away at every tree in sight to get enough fuel for the day's cooking. Impossible! you might say. Yet this will be a commonplace sight in a couple of decades if we don't take steps right now to meet the growing gap between the supply and demand for cooking fuel, especially in the rural areas. For, rural electrification has proved a flop and up till 1979 barely 50 per cent of India's villages had been electrified. People are heavily dependent upon kerosene and fuelwood. Even Reserve Forests are being stripped for fuelwood, thus reducing the forest cover of the land and leading eventually to soil erosion and floods.

What is needed is a totally new approach to forestry, in which the forest official is not merely concerned with protecting the existing forests but also with planting more trees on every available bit of land to meet the hunger for fuel. In this new approach—Social Forestry—not merely the officials and the governmental machinery but the whole populace is involved. In fact, tree plantation will have to be the second Green Revolution.

There is enough land available to plant trees, not only for energy but also for timber, pulp and other industrial uses. Trees incidentally, beautify drab surroundings and provide shade to the travellers The suitable areas have to be identified, the most suitable species planted, the saplings protected from man and animals during growth and harvested at the right stages of maturity, the produce shared with the people and corrupt officials and contractors eliminated.

P M Ganapathy

Anogeissus latifolia (dhausa) is common to most of the dry, deciduous forests of India. The purplish-brown wood is harvested from natural stands near urban areas and sold as firewood. Besides fuelwood, the wood is much used for the shafts and axles of carts—hence known as the axlewood tree

Neem

The three most popular trees that can be grown practically throughout India are neem (*Azadirachta indica*), (family Meliaceae), eucalyptus, popularly called Nilgiri (family Myrtaceae) and Su(Ku)babul or *Leucaena leucocephala* (family Leguminosae: Mimosoideae). These, therefore, have a place of pride in Social Forestry.

Neem has many uses besides fuel. Its wood is resistant to decay, the straight, strong poles are excellent for building construction and making furniture. The trees provide shade and serve as wind-breaks and shelter belts, protecting cultivated land from wind erosion and evapo-transpiration. The oil extracted from the seed is used for lamps and as lubricant for machinery. Neem cake is an excellent fertiliser and simultaneously acts as an insect repellent and systemic pesticide. The bark contains about 40 per cent tannin of superior quality. Neem oil is used in the preparation of soaps, disinfectants, pharmaceuticals and cosmetics. The leaves can be used as emergency fodder.

Eucalyptus is good as firewood, charcoal, timber and a source of paper pulp. It is used for building construction, fence posts and stakes. It makes a good wind-break, shelter belt and also serves as a source of honey nectar for honey bees. The lemon-scented oil is rich in citronella, used in the perfume industry.

Subabul

Subabul (see also p. 51) provides protein-rich, nutritious and palatable green fodder for the cattle. Once established, it can yield 70 to 100 tonnes per hectare under irrigated conditions in eight or nine cuttings per year for more than 15 to 20 years. The varieties most suited for fodder production are Cunningham, Peru and K-8. The Hawaiian types are low-yielding and are best suited to arid and semi-arid conditions. The fuelwood of Hawaiian Giants (Salvador types) arboreal varieties K-8, K-28 and K-67 have an average density of 0.54 and a calorific value of about 4,300 kilo calories per kg of oven-dry wood. The value for Hawaiian types is a little higher—4,660 kilo calories. Its density is 0.70; it is, therefore, superior to the Salvador types in heating value. But the total biomass per hectare is much less than that of the Giant varieties which are classified as medium-hard woods. The trees can be coppiced every three to five years, depending upon soil and moisture conditions. The annual growth reported from the Salvador types varies from 24 cu m to 100 cu m, but is usually 30 cu m to 40 cu m per hectare. The trees coppice vigorously in cycles of five to six years, and are known to stand more than 50 years.

Subabul wood is used for floor joists, girders, rafters, sheds and household furniture. For timber purposes, the trees should be left standing for eight to ten years.

Charcoal from Hawaiian type Subabul has a heating value of about 7,000 kilo calories per kg, which is 70 per cent of the heating value of fuel oil. The Salvador types may have a lower heating value than the Hawaiian type. The wood can be used to fuel electricity generators, rail and road locomotives, dryers for fish, tobacco, grain and other agricultural products, tin smelters, brick and charcoal kilns, saw mills and for generating steam. Charcoal can be used to produce calcium carbide, pig iron, ferro alloys including steel, and other industrial products.

The pulp yield is about 50 per cent. The bark is thin and constitutes only eight per cent of the total wood. The length of the fibre is about 1.20 mm, width 0.025 mm, lumen (the space within the cell) width 0.015 mm and the cell-wall thickness 0.005 mm. Leucaena wood fibre is shorter than that of pine wood; compared to conifer pulp, it has low tearing strength, low folding endurance and average tensile strength. Kraft pulp is suited for printing and writing but not for high-strength bag and wrapping paper. It is best suited for blending with long-fibre pulps for printing and writing paper. The dissolving pulp can be used for production of rayon or cellophane. The wood from a 24-month old stand was tested for pulp at the Mysore Paper Mills Ltd, Shimoga (Karnataka). The unbleached pulp yield was 42 to 45 per cent.

Subabul is an excellent organic manure, as the shoots, about 1½ m long, can be cut and buried into the soil to improve the fertility of the land. Fertiliser prices are rising every year and their use is declining, particularly with small and marginal

Land for social forestry

SOCIAL FORESTRY involves planting trees on lands outside the reserve and protected forests. Such lands are: (a) Degraded forest lands, (b) Waste lands, (c) Community, Panchayat and common lands, (d) Road-sides, canal banks and railway lines and (e) Private lands.

Degraded forest lands: These are the result of high population pressure, both human and animal. There has been a wanton destruction of trees for fuel and timber, and heavy browsing by animals. With the construction of dams, hydro-electric works, canals, roads, railways, industrial installations and townships, etc much forested land has had to be cleared. The displaced persons from such areas were settled by cutting down more forests. As they felled trees for fuel and fodder, in course of time, the soil of the lands thus exposed has been eroded by rains and high winds; such lands have become barren. In areas with rainfall exceeding 700 mm per year, Subabul can be planted as the main species.

If the soil is deficient in elements like phosphorous, calcium, potassium, sulphur, zinc, boron, iron and molybdenum, this should first be corrected by applying micro-nutrients. Small tanks can be built to store rain water, which can be recycled to accelerate the growth rate of the plants. People in the neighbourhood should be employed for uprooting wild bushes and weeds, field preparation, digging of trenches and pits, raising nurseries, transplanting and manuring in the field.

If the expenditure involved is heavy and public funds become a limiting factor, some of the areas can be farmed out to entrepreneurs or corporate bodies, preferably to groups of enthusiastic young graduates of agriculture and engineering on long-term lease at concessional rates. The gum industry will get the seeds for extraction right from the second year of Subabul planting onwards. Plants germinating from seeds falling on the ground will yield protein-rich fodder in five to six months. Thus, Subabul growing can become a labour-intensive activity which will directly benefit the people living in the vicinity of the forest.

The other important popular trees in north India, apart from Neem and Eucalyptus which can be grown with Subabul are *Acacia nilotica* (Babul), *A. catechu* (Khair), *Dulbergia sissoo* (Shisham), *Zizyphus mauritiana* (Ber), *Albizzia lebbek* (Siras), *Albizzia procera (Safed Siras)*, *Prosopis juliflora* (Vilayati Babul) and *Madhuca latifolia* (Mahuwa). Subabul is not suited to arid conditions except in low-lying areas with higher moisture content.

In the southern plateau it can be associated with *Acacia nilotica*, *A. catechu*, *Casuarina equisetifolia*, *Dalbergia sissoo*, *Gliricidia maculata*, *Gmelina arborea*, *Pithecolobium dulce*, *Tamarindus indica* (Imili) and *Hardwickia binata* (Anjan), and in the eastern states with *Gmelina arborea*, *Moringa oleifera*, *Albizzia lebbek*, *A. procera*, *A. chinensis* etc.

Waste lands: Waste lands are very extensive; they remain unproductive and deserted. Subabul is tolerant of saline alkali conditions. Hence, it could be introduced successfully in some of the saline-alkaline soils, ravine lands, lateritic soils, coastal areas, grasslands and shallow black soils. At the Nanodara Station of the Bharatiya Agro-Industries Foundation, about 65 km from Ahmedabad, Subabul has been successfully established on 40 hectares of sandy saline soil where the well water has a salt content exceeding 3,000 ppm. It is very important that such areas be kept well drained, as Subabul does not tolerate water-logging. If there is any pan formation, it should be broken up by deep ploughing to facilitate leaching of salts, in the monsoon season. The other trees tolerant of saline conditions are *Acacia nilotica*, *Albizzia procera*, *Azadirachta indica*, *Prosopis juliflora*, *Pongamia pinnata*, *Tamarindus indica* and *Eucalyptus* spp

Ravine lands

For the ravine lands, the trees most suited are *Albizzia lebbek*, *Acacia catechu*, *Acacia nilotica*, *Ailanthus excelsa*, *Dalbergia sissoo*, *Eucalyptus* spp. Subabul will also be found to grow well as it has a deep tap root system, which can penetrate through such type of soil.

Subabul can be easily established in coastal areas along with *Casuarina equisetifolia*, *Pongamia glabra* and *Prosopis juliflora*. *Eucalyptus tereticornis*, *Acacia auriculiformis* and Agave also are promising species for such soils. As regards afforestation of grasslands, Subabul is the ideal plant as it can very easily establish itself and later on shed its seeds in the surrounding areas, thereby increasing the fertility and carrying capacity of coarse and neglected grasslands. The shallow, black cotton soils are other areas which do not support much vegetation in the Deccan plateau. Wherever the rainfall is adequate, Subabul seedlings can be easily established in pits or trenches. *Acacia nilotica*, *A. catechu*, *A. leucophea*, *A. modesta*, *Prosopis juliflora*, *Eucalyptus tereticornis*, *Madhuca latifolia*, and *Melia azadirachta* have also been found successful.

In community, panchayat and common lands, afforestation is more a problem of management and harmony among the collective owners of such lands, rather than of techniques involved in raising the trees. Under such circumstances, strong leadership and motivation are necessary to make the project successful. Alternatively, the village panchayat may receive subsidies and loans on easy terms from the government, and undertake the planting and protection of trees. The villagers may be given the fuel wood at concessional rates up to a specified limit and the rest of the wood sold in free market at competitive rates. Subabul being very fast growing will be ready for cutting earlier than most of the trees mentioned earlier in the different agro-climatic zones.

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farmers. A small area under Subabul will provide cheap organic manure to build up the fertility of the land. These uses apart, Subabul can be used as a wind-break, shelter-belt and a shade plant. As it remains ever-green, it can also be used as a fire-break in the forest, to check the spread of forest fires. It is by far the best plant available for rehabilitating eroded steep hill slopes and barren, marginal and sub-marginal soils. It can suppress the worst type of weeds, including *Parthenium* (popularly called the congress or carrot grass) *Lantana* and *Imperata*.

Subabul is used as food in Central America and Indonesia. Young leaves and small pods are eaten raw or cooked in soups, tacos, etc. Mature seeds are roasted, and young dry seeds are popped. It should not be eaten too frequently and should be cooked in iron vessels to detoxify the toxic chemical mimosine, contained in the leaves, which causes loss of hair if consumed. As a cottage industry, the seeds can be boiled with hot water to extract gum which resembles guar gum, carob bean gum, or gum arabic. Dyes can be extracted from Subabul for dyeing wool and cotton cloth. On boiling with water, the young pods produce red pigments and old pods, varying shades of brown.

Finally, with its cascades of emerald leaves and fragrant flowers, it is used as an ornamental tree.

Choice of trees

The decision on the type of trees to be planted will depend upon the size and quality of the land and the pressing needs of the villagers. *Acacia* species, Neem, Eucalyptus, Albizzias, Sissoo and Subabul will be the choice in most places, for different purposes. In other situations, the choice may be *Casuarina*, *Gliricidia*, *Pongamia*, Bamboo and *Sesbania grandiflora*. A few trees of tamarind, jamun, sitaphal, mango, amla, chickoo, ber, jackfruit and pomegranate may be added to meet the requirements of the village. The management of different types of trees will require expert knowledge, the care and other practices involved in raising such a "tree mix". The extension wing of the Forest Department is generally quite helpful in supplying the knowhow. In some cases, there may be preference for fuel and fodder of only a few selected species to which the farmers are well accustomed. It is therefore necessary to streamline and finalise all details before embarking on such a venture. Afforestation of these lands is a real challenge and the experts in the Social Forestry Division will have to exert themselves in making it a success.

Planting of trees and their maintenance on the road sides, railway lines, canal banks, lakes, etc will be chiefly the responsibility of the State Governments or the District Local Boards. There is enough experience of handling such projects in the past. Even today one can see very good stands of some trees, planted more than 100 to 150 years back, beautifying the landscape and providing shade to the travellers. Trees are also useful as wind-breaks and shelter belts, preventing excessive loss of moisture by evapo-transpiration from the fields and crops. They cut off the noise of locomotives and other vehicles and, absorb dust.

As more and more roads, railway lines and canals continue to be built, plans should include sufficiently large strips of land for five or six rows of trees on either side of them. The first rows will include plants of aesthetic importance, shade, edible fruits, seeds of economic value and timber such as sissoo, neem, gulmohar, Eucalyptus, Jamun, Mango, Tamarind, Siras, Rain-tree, Karanj, Mahuwa, Banyan and Pipal trees Only a single type of tree should be grown for a few kilometres, then another type in a similar manner. Growing many types together, one after the other, will become monotonous and lose its aesthetic value. The distance between plants may be kept four to five metres, depending upon the species. The consecutive rows should be three metres apart and may be planted with Subabul, Siras, Teak, Khair, Babul, *Casuarina*, *Acacia auriculiformis* and Bamboos.

Quite often, the roads are widened too frequently to meet the demand of growing heavy traffic. Hence, several rows of trees should be planted; if only two or three rows are planted on either side, they will be pulled down and nothing will be left.

Some of the lands with private farmers may not be fertile enough to support agricultural crops. Elsewhere, irrigation facilities may be absent or inadequate. Such type of lands can be put to forestry. The trees selected should be drought-tolerant like the *Acacia* species, along with fast-growing Subabul and a few fruit trees. They will be more remunerative and will survive the aberrations of weather much better than the grain or cash crops, which receive a very severe setback from prolonged drought during the critical stages of growth. Trees, on the other hand, have the capacity to absorb such shocks without much damage. Alternatively, the growing of food and cash crops may be combined with trees in a system called "agro-forestry". Similarly, poor pasture lands should be partially covered with trees to supply fuel, timber and grass in the silvopastoral system. In both systems, the trees will provide the necessary shade and reduce the water requirements of crops and grasses and save them from total loss during drought.

Finally, since the population pressure will continue, the demand for fuel-wood will keep increasing. Its price will rise beyond the puchasing power of the rural poor. This makes it imperative for private farmers to grow suitable species of fuelwood on the boundaries of their lands and also on some of the field bunds. The tree lines should be widely spaced so as not to shade the agricultural crops excessively.

As part of the tree planting effort, the beautification of towns and cities should also receive greater importance. Trees like *Bauhinia variegata*, *B. purpurea*, *Cassia fistula*, *C. marginata*, *C. javanica*, *C. nodosa*, *Lagerstroemia flosreginae*, *Peltophorum ferrugineum*, *Pithecolobium saman*, *Butea frondosa*, *Erythrina indica*, *Jacaranda mimosaefolia*, *Delonix regia*, etc are a feast for the eye. These trees should be planted on roads, avenues of bungalows, offices, schools, colleges, hospitals, places of worship, in the parks, around wells, tanks, ponds, bus stands, and near railway stations.

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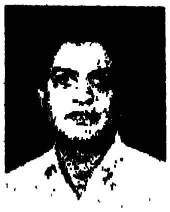

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forests for fuel

Subabul — the superb fuelwood tree

L. L. Relwani

... More rewarding than any other crop—other things being equal

IN RECENT years, Subabul, an evergreen leguminous shrub originally grown by the Maya and Zapotec tribes in Mexico thousands of years ago, has been hailed as the "miracle", "wonder" or "divine" plant and the "plant of hope". A superlative fuelwood tree, it can be put to multiple uses; it can give high-protein fodder, fuel, timber, organic manure, and provide shade in cacao, quinine, coffee, tea, vanilla and other plantations. It has a high rate of growth, the Salvador or Giant varieties growing five to seven metres in height and four to five centimetres in diameter at breast height in a year. More importantly, trials at the Bharatiya Agro-Industries Foundation (BAIF), Uruli Kanchan (near Pune in Maharashtra State), show that it can be grown on wasteland and yields higher returns, without much managerial skill, than any other cropping system involving agricultural or horticultural crops under similar conditions.

Subabul *(Leucaena leucocephala)* is a thornless, perennial shrub with feathery leaves, small, powder puff-like fluffy flowers and bunches of long, greenish pods which turn brown on maturity. Its aggressive tap-root system penetrates even hard rock. It fixes 500 to 550 kg of atmospheric nitrogen per hectare per year and improves the fertility of barren land. It can act as a wind-break, a shelter belt, an ornamental tree and as fire retardant in a forest because of its evergreen nature. The vigorous tree of the ancient Mexican tribes has now spread to a number of countries. Called 'ipil-ipil' in the Philippines, 'camtoro' in Indonesia, 'koa-hoale' in Hawaii, horse tamarind in Australia, it is commonly known as ku-babul in India. In view of its uses, however, the second National Seminar on Ku-babul held at Uruli-Kanchan from 26 to 27 June 1981 resolved to change the name from Ku (bad)-babul to Su(good)-babul.

The plant grows best in places where the rainfall ranges from 750 to 2000 mm, especially from June to November. If protective irrigations can be provided once in four to six weeks, it can grow from Kanya Kumari to the frost-free foot-hills of the Himalayas up to a latitude of 32° to 33° North. The optimal altitude is from sea level to 500 metres, although there is no appreciable loss in growth up to an altitude of 800 metres in the tropics. Beyond this elevation, it will lose its vigour gradually up to 1300 metres and thereafter cease to grow; due to severe cold and lack of sunlight for photosynthesis in the winter season.

Two-month old Subabul seedling ready for transplanting in the field

It thrives best on a loamy and fertile soil rich in phosphorus and calcium and micronutrients like zinc, iron and molybdenum. Acid soils should be limed to pH 6.5 and sodic soils beyond 8.5 with gypsum. With good distribution of rain, Subabul can be established even on steep hillslopes and marginal, gravelly, sandy and saline lands. Only acidic and water-logged soils are detrimental to its germination and growth.

On fairly level land with a soil depth of 50 to 60 cm, seeds may be drilled directly in furrows two metres apart. Spacing of seedlings may later be thinned to 25 to 30 cm within the rows. Alternatively, pits 30 cm on each side (1ft × 1ft × 1ft) are dug about one month before the monsoons. They may be spaced 1m × 1m or 2m × ½m. In less fertile soils and lower rainfall areas, the spacing can be increased to 2m × 1m or 3m × 1m. In pasture lands, the spacing may be as wide as 3m × 3m to 4m × 4m to provide shade preventing excessive loss of soil moisture by evapotranspiration. In hilly areas, staggered trenches may be dug along the contours two to three metres apart and seedlings spaced at 1m to 1.5m, depending upon moisture conditions.

Before sowing the seeds either directly in the field or in polythene bags in the nursery, they should be dipped in hot water at 80°C for five minutes and further put in wet gunny bags for 12 to 24 hours to soften the coat for easy germination. After drying for one hour they should be smeared with rhizobium bacteria NGR8 for neutral and alkaline soils and CB 81 for acid soils. At the BAIF, Uruli Kanchan, the mixture of both the cultures has shown better growth rates for soils with a *p*H range of 7.5 to 8.0.

The trees will be ready for harvest after three to five years, depending upon the environmental conditions. The growth rates of K-8 Hawaiian Giant, observed at the BAIF, Uruli Kanchan (rocky murum soil, 5 cm depth, 400 mm rainfall, 560 m altitude and 18.5°N latitude) are as follows:

Under irrigation: Two-month old seedlings raised in polythene bags were transplanted at a spacement of 1m × 1m on 9 September, 1976. In 2 years the trees averaged a height of 9.5 metres and diameter at breast height (DBH) of 6.0 cm (18.84 cm girth), and 10.5 m height and 8.0 cm DBH (25.12 cm girth) in 3½ years. At this stage, alternate rows were harvested and allowed to coppice. With the increased spacing, the remaining trees showed rapid growth rates and reached 13.50 m height and 12.37 cm DBH (38.84 cm girth) in 4 years 2½ months. The rate slowed down again when the coppiced plants grew from the base. The coppiced plants attained 4.55 m height and 2.67 cm DBH (8.38 cm girth) in 9 months, and 5.77 m height and 3.14 cm DBH (9.86 cm girth) in 14½ months.

and 2.67 cm DBH (8.38 cm girth) in 9 months, and 5.77 m height and 3.14 cm DBH (9.86 cm girth) in 14½ months.

Avenue trees spaced 4 m x 2 m had a height of 13.40 m, 21.10 cm DBH and 66.25 cm girth after 4 years and 3 months. Trees grown by direct sowing of seeds attained 12.88 m height, 12.66 cm DBH and 39.75 cm girth in four years.

In all the three instances, four irrigations were given once every six weeks from November-end to May-end.

Under rain-fed conditions: Two-month old seedlings transplanted on 8 July 1977, without any land preparation, with a spacing of 3m × 1m, attained a height of 10.18m and a DBH of 9.87 cm (30.99 cm girth) in 3 years 11 months. There was a considerable fall of dried leaves in the summer season, particularly on the periphery of the forest. Fresh growth reappeared with the first showers of rain and the vigour was maintained till the end of the spring season.

From the four examples, it may be concluded that Subabul can be grown even with meagre rainfall. The growth rates can be accelerated by a few irrigations in the summer season. Wider spacings help in increasing the diameter of the trees rather than their heights.

Two-year old stand of Subabul planted 1m x 1m

Economics of fuel production

From the experience gained, it has become evident that assured returns from Subabul are possible with increasing rainfall from 700 mm to 1250 mm and above on neutral to alkaline soils with a depth of 50 to 60 cm. Yield of wood, after drying for one month to 30 per cent moisture, can easily reach 40, 80 and 120 tonnes for zones having rainfall of 700 mm, 1000 mm and 1250 mm per annum, respectively, in a cycle of five years. By providing an irrigation every six weeks, the yields can be raised to 150 tonnes per hectare in a cycle of three years. With timely irrigation in summer, the trees will maintain vigour all through the year in the tropics without any setback and fall of leaves.

The estimated economics of planting for these four situations are given in Table 1. There is a likelihood of a slump in the price of seed, unless a large-scale programme is taken up throughout the country and the

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industry comes forward to extract gum from seeds which has a great potential for home consumption and export. The seeds contain about 27 per cent gum. The current price of certified seeds of K-8 variety is around Rs. 50 per kg and much higher when imported from outside. The prices of seeds and wood are expected to rise 4 to 5 per cent every year. So will the wages of labourers. Since the balance will always be in favour of output rather than input, net profits are expected to rise with each cycle.

The net profits from Subabul cultivation, without much managerial skills, are higher than in any other cropping system involving agricultural or horticultural crops under similar agro-climatic conditions. Vast stretches of lands lying waste and barren can be quickly afforested to yield profits and to change the ecosystem within three years from one of dreary desolation to that of lush, green flourishing forests, as demonstrated at Uruli Kanchan.

Subabul wood for making pulp

Subabul is a medium-hard wood and is easily converted into pulp and paper. One tonne of pulp requires 2.3 tonnes of air-dry wood (6 per cent moisture). One hectare of Subabul will produce about 100 tonnes of such wood in three years with four or five protective irrigations in the summer season, or 33 tonnes per year. Allowing for 12 per cent bark and 8 per cent lops and tops, 26.4 tonnes of air-dry wood or 11 tonnes of pulp can be obtained per year. Thus, for a factory handling 11 tonnes of pulp per day, 365 hectares of Subabul will be required per year, or about 1,100 hectares for a three-year cycle.

From the same area a minimum of 1,825 quintals of seed will be available in the first year, 3,650 quintals in the second year and 5,475 quintals every year from the third year onwards. Even if only 20 per cent gum is extracted from the seed, 365 q, 730 q and 1,095 q of gum will become available from the first, the second and the third year onwards, respectively. The residue left after gum extraction can be used as a protein-rich cattle feed component. Additional stocks of seeds can be purchased from the market where it will be freely available after three to four years for increasing the output of the processing unit. The small branches of trees can be used for fuel and the leaves converted into leaf meal (27 to 30 per cent protein) by drying in the sun for a few days and converted into cattle feed. (See also article on p.48)

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forests for fuel

THE PROBLEMS OF FUELWOOD POLICY

K. R. Datey

What are the constraints on fuelwood? How do we choose between the different uses of wood and other biomass?

FUELWOOD as an energy source, especially for domestic and non-commercial fuel consumption, is an attractive proposition for more than one reason. Unlike coal and other fossil resources, it is renewable. On the other hand, unlike other alternative energy resources like biogas, it is easy to store, preserve, handle, transport and can be suitably subdivided for decentralised marketing. Studies on various species (like Subabul, Eucalyptus, Casuarina, etc) also indicate that it is possible for fast-growing, short-rotation plantations to give good yields. Thus, the potential that fuelwood plantations hold is now fairly clearly established. It is now important to concentrate on the problems which go into shaping a viable fuelwood policy.

In the first place, present yield estimates suffer from a major limitation. The main factors influencing biomass yield are not sufficiently isolated. Nor is a quantitative input-output analysis adequately worked out. This is important if the data are to be used to estimate yields in highly dissimilar conditions. An example is the way studies deal with the question of water.

Biomass yield does not only depend on total rainfall, its distribution and the methods of soil water management (type and number of irrigations, etc). It also depends on the moisture replenishment from irrigation or the subsoil. This is because the key factor here is *utilisable* moisture. Yield estimates will receive a firm foundation when related to this factor, and more importantly, can be much more easily extrapolated to dis-similar situations. Thus, for example, areas where the subsoil holds much more water, even if the surface soil does not, will give much higher yields which cannot be extrapolated to truly arid conditions.

In the same way, careful accounting is necessary for available or utilisable soil nutrients, natural organic matter, chemical fertilisers, available nitrogen for leguminous plants or green manure from leaves. All these are important because a viable policy must finally be based on a cost-benefit analysis which also takes account of the trade-offs between the factors or their alternative uses. Leaves, for example, may be recycled as manure or sold as by-product. Most data currently reported do not have a satisfactory framework for cost-benefit analysis which isolates and incorporates the key factors

This affects the values on which projections are based. Most studies base their projections on yield estimates of the order of 40 to 60 tonnes per hectare per year. This is somewhat optimistic. Especially since most studies agree that fuelwood will have to be grown on land which has undergone deforestation and fallen into disuse, arid and marginal land, wastelands, etc. Our estimates (based on a value of 0.2 to 0.3 tonnes per hectare per year per cm of utilisable water for the less efficient plants like sorghum, and 0.3 to 0.5 for more efficient plants like sugarcane) suggest a yield of about 12 tonnes per hectare per year as a more realistic estimate in arid climates without irrigation.

Estimated yields become a crucial factor in face of the trade-offs which a fuelwood policy involves under conditions of low yield. Fuelwood represents one among the alternative uses of biomass from non-agricultural lands; structural material (timber or bamboo), fibres, polymers (like rubber and other latex), feed stock for chemical production like furfural or pulp, fodder and food for animals are the alternative choices. Under conditions of low yield, fuelwood will definitely involve a trade-off against them.

At present, the productivity of Indian forests is extremely low; with current practices, fuelwood yields from forest lands would be of the order of barely 4 to 5 tonnes per hectare per year. With such a low productivity, choosing alternative bioconversion processes for producing chemicals, and the production of small dimension timber and bamboo for infrastructure and community buildings of improved design may turn out to be a much better choice. If the problems of process heat and cost of equipment for bio-conversion processes can be solved by using renewable energy and resources to the full-set extent, these alternative pathways will generally yield better and diversified uses, more value, and generate a broader spectrum of employment, incomes and benefits. In view of this, it is perhaps best to restrict the use of biomass as fuelwood to meet mainly domestic and non-commercial needs.

In addition to the low forest productivity, another factor constraining the use of wood as fuel, is the unfavourable land to man ratio in India. Countries like Sweden and Norway could use fuelwood for electricity generation because with their very favourable land to man ratios they can afford to use less efficient but easier paths. India, however, must think twice before going in for fuelwood as a replacement for industrial fuels for energy. Moreover, our low land to man ratio also means that we cannot have a viable fuelwood, or for that matter biomass, policy without increasing the productivity of our existing forests.

Fuelwood as an industrial energy source has its own problems. It has to compete with more direct, and so, more efficient ways of conversion like wind, solar and small hydro energy (efficiencies of 8 to 10 per cent are obtainable as against the one per cent in photosynthesis when supplemented by adequate water supply). The technological possibilities of mechanical power and heat energy by conversion of solar and wind energy have not yet been fully developed. In a tropical country like India, solar energy supplemented by wind and small hydro energy is a very promising combination—effective because the seasonality of each source complements that of another. Today, utilising such a combination is limited by technologies which have to use scarce energy-intensive materials like steel, aluminium, and cement.

Studies have shown that the consumption of energy-intensive materials per unit capacity and output is much higher for renewable sources than for conventional sources such as coal based thermal or even hydro-energy This includes the cost of transmission and generation. On the other hand, two hundred years ago, water-wheels and wind-mills were built entirely out of locally available and biomass based materials. The largest windmills were of such a size that with a modern design it could produce up to 200 kW. So there is another choice one must give serious thought to—should we concentrate on replacing fuel by wood, or on replacing other non-renewable sources by solar, supplemented by wind and small hydro, energy and reducing the use of materials like steel and cement by wood and biomass derived materials like timber or polymers, etc?

The choice, even if of a second order nature, can be much more effective. Since initial photosynthesis efficiency is as low as one per cent when water supply is adequate, it is much more sensible to use biomass as a tool in lowering the cost of exploiting other renewable sources which are also more efficient.

An important aspect of fuelwood plantations, and social forestry programmes, is the nature and extent of their impact on employment. Initial studies based on a comprehensive input-output model become quite important here. If employment is seasonal, the time and place have to be related to local needs. Migration, and seasonal migration particularly, are a problem that can aggravate disproportions between the demand and supply of labour and cause much hardship; some areas may be starved of labour while it becomes surplus in even adjacent areas. The trouble with plantations is that the component of employment that goes into maintainance and utilisation is much smaller that what goes into the initial preparation and planting. The increased initial demand even draws off people from other, customary employment for short periods, only to slump drastically later. This is itself a traumatic, destabilising influence. Every care, therefore, has to be taken to ensure proper scheduling and development of sustained employment.

In changing over to high yields, we are also changing over to a different level of technology. Traditional forestry gives place to agro-silviculture. This carries with it a different and demanding structure of tasks and skills. These are things which change slowly, and here too, if social forestry is to become adequate to local needs, a phased development of forestry programmes is needed; not a 'crash programme'. Otherwise, as happens in a number of industries coming up in underdeveloped areas, the local population is bypassed or forced into skilled low-paid categories of employment because it cannot sufficiently upgrade its skills. If local needs are not satisfied, then unauthorised fuelwood collection and selling, often at low prices, will remain a problem and may finally even be counter productive.

The most sizable section of the population to be directly affected by social forestry programmes will be the Adivasis. For this poorest, almost marginalised, section of our people, social forestry programmes present a dilemma. If social forestry programmes are implemented with the Adivasis in view as entrepreneurs, the pressure of market mechanisms forces control out of their hands. It is doubtful whether they can weather either the fairly prolonged periods of gestation, or the market fluctuations in the product if fuelwood becomes widely available. As with so many other products in the past, control is likely to pass into the hands of traders and such intermediaries.

On the other hand, things will not be relieved simply by entrusting government organisation with the social forestry programmes. In the first place, the Adivasis would then be reduced to becoming wage labourers and, previous experience suggests, perhaps even bonded labourers, without receiving the full benefits of the programme. The dilemma can be resolved by sacrificing a unifocal solution. A judicious combination of an efficiently managed planned forestry under state control, and small agro-silvicultural plots allotted to marginal-farmers and landless labour, worked intensively, represent one of the way out.

To sum up, we have now reached a stage where we need to concentrate on translating the potential of fuelwood and other biomass into a viable policy. This needs a comprehensive quantitative input-output analysis of the factors which determine biomass yields, which alone will allow a cost-benefit analysis and the extrapolation of results to different areas. At a macro level, we have to choose between the different alternative uses of biomass and the place that fuelwood occupies in it. We then have to take account of how the policy package will influence the employment and economic position of the local population. The present level of analysis is quite inadequate, and we first need an analysis which takes all these factors into account before we commit ourselves to a firm fuelwood policy.

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FUEL-EFFICIENT STOVES

ANOTHER approach to be considered in reducing the demand for firewood is the introduction of more efficient burning equipment. This approach seems particularly attractive because firewood is most scarce in those regions of the world where it is also burned most inefficiently.

Roughly 80 per cent of the fuelwood consumed in developing countries is used for domestic purposes—cooking, space heating and hot water. Many traditional cooking stoves and open fireplaces waste wood mainly because they focus the flames poorly on the cooking surface.

Improving wood-burning devices seem to be one of the best ways to alleviate the twin curses of firewood scarcity and forest depletion. Often, all that is required is very minor redesigning of existing stoves.

Improved stove models are insulated to prevent heat loss through the walls. The hearth can be closed to regulate air intake and improve combustion conditions. The flow of air and hot gases through the stove is directed to concentrate heat on the cooking surface. A chimney is usually incorporated into the design to provide draft, the motive power that provides air for combustion. (If poorly designed, however, chimneys can decrease efficiency by creating excessive draft.) Cooking pots are arranged to fit the stove properly, preventing leaks and heat loss.

Improved stoves can probably achieve an overall efficiency of 20 to 30 per cent and they have the potential for reducing wood requirements by five- to ten-fold. The wide dissemination of such stoves could reduce the time, energy and money that Third World women now spend acquiring fuel and cooking.

The other approximately 20 per cent of fuelwood used in developing countries is burned at similarly low efficiencies in small- and medium-scale industries such as food processing and manufacturing. There are numerous ways in which modern engineering principles can be applied to improve the fuel efficiencies of these technologies.

In many cases, fuelwood savings can be realised even without changes in equipment. Perhaps the best way to do this is simply to dry or season wood before burning. When burned, moist wood produces less useful heat and more smoke. To ensure that wood is dry it should be split (in the case of large logs) and stored for six months.

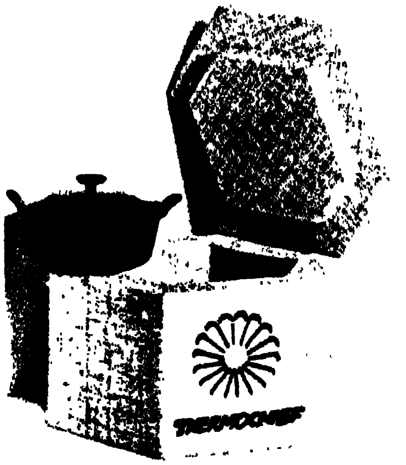
An open fire may extract only 10 per cent of the energy potential of wood; an improved stove can use 20 per cent or more. If such stoves were universally adopted in areas where open kitchen fires are used, the demand for fuelwood would drop significantly.

Efficiency can also be increased by designing better cooking pots, by improving insulation and house-heating systems, and by finding better techniques for air-drying fuelwood.

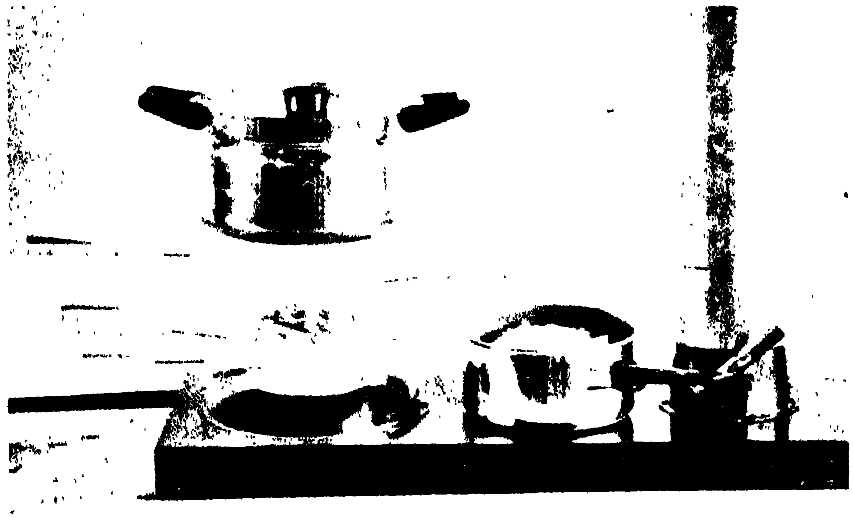
The issues to be considered when advocating use of more-efficient stoves are much broader than simply energy-efficiency or even fuel costs. The kitchen, in effect, is a miniature food-processing plant where the time and effort involved in preparing the food and fire and in the cooking and clean-up are all important factors in the efficiency calculations. Moreover the case, and the prestige, of using a gas stove should not be underestimated

Tradition remains the most serious barrier to the use of new stoves. Considerable extension work and demonstration may be needed to convert people to the use of new stoves. In some cases, unexpected problems may arise. For example, some Nepalese villagers recently abandoned highly successful and widely adopted stoves when their roof thatch, no longer infiltrated by smoke, became infested with termites.

Excerpted by permission from *Firewood Crops*, a report of the Board on Science and Technology for International Development, National Academy of Sciences, USA.



"Fireless" cooking. If a heavy pot of food is brought to a boil and then placed inside a heavily insulated box, it continues to cook in its own heat. No additional fuel is needed, thus saving much firewood. The system is particularly useful for beans, sauces, stews, and other foods that are cooked slowly over several hours. Hot stones can be added for further cooking.



The Family Cooker. Based on efficient cooking stoves developed in the Netherlands during World War II, the Family Cooker was developed at Eindhoven University. Efficiency is optimised by reducing heat losses and controlling combustion. The housewife has easy and flexible control over the rate of cooking. This is because air for the fire is sucked in through the air-inlet pipes and controlled by the damper in the chimney. Heat transfers efficiently because the fire plays directly on the cooking pot and cannot escape sideways. Flue gases then pass downwards, heating the inlet air and a "hotbox" that can be used to preheat food or water or to keep cooked food warm.

M. Bernriess—FAO

Charcoal making in pit or earth-covered mound in Tunisia

forests for fuel

WHY NOT USE CHARCOAL?

K. Seshagiri Rao R. Vaidyeswaran

Charcoal makes wood energy easier and cheaper to transport, and the growing reliance upon it is the result of the increasing distance from the harvest site of wood to the user

THE fuel consumed in kitchens accounts for about half the total energy consumed in the country. It also accounts for almost the entire consumption of non-commercial fuels (agricultural and farm wastes, firewood, etc). For at least another decade, the quantity of non-commercial fuels is likely to remain more or less the same, though the proportion (see Table 1) is likely to decrease with the increasing availability of commercial fuels like kerosene, coke and liquefied petroleum gas (LPG).

Firewood is the main non-commercial fuel used in India, especially in rural households. The quantity consumed is about 120 million tonnes (mt) and this figure is expected to remain at the same level for many years. During the past few years, however, serious doubts have been expressed about the adequate availability of firewood in view of widespread and rapid deforestation.

In fact, forest resources are dwindling faster they are generated. As it is a replaceable or renewable fuel resource, firewood should be given top priority in the overall energy plan and urgent steps should be taken to cultivate quick-growing trees for use as fuel. Firewood is used as such in rural and urban areas for fuel purposes. Sixty per cent of the consumption is in urban areas. It may be difficult to stop its use in rural areas, for, often it does not come under the monetised economy. However, in urban areas, its direct use should be stopped as it causes environmental pollution. Its efficiency of utilisation is also low—10 per cent. On the other hand, it can be processed to more efficient forms of fuel like charcoal or gas.

Taking into account the relative efficiencies of combustion of wood and charcoal and their calorific values, it is more efficient to convert wood to charcoal and burn it rather than burn it directly. This is apart from charcoal being smokeless.

The method of making charcoal by destructive distillation of wood is the oldest wood-processing method. Charcoal is an ideal smokeless fuel for cooking. The gross calorific value of charcoal ranges from 6,000 to 6,500 K.cal/kg. The calorific valueof other fuels (in K.cal/kg) is as follows: soft coke—4,500—5,000; firewood—3,000—3 500; dung cake—1,800—2,000; and kerosene—11,000. One kilogram of charcoal has a replacement value of 2.38 kg. of firewood. The combustion efficiency of charcoal in the existing *sigrees* is about 28 per cent. Thus, conversion of firewood into charcoal for use as a fuel will be better than using firewood as such. Charcoal is also useful as a reductant in electro-metallurgical industries and in the manufacture of calcium carbide, carbon disulphide and active carbons. It does not contain sulphur, which is an advantage for metallurgical purposes.

Destructive distillation or carbonisation is the process in which any carbonaceous material is heated out of contact with air. The residue from wood carbonisation, after the major volatile products are removed, is the charcoal. Depending upon the temperature at which charcoal is made, the composition and residual volatile matter differ. Charcoal is normally made by heating wood to about 400°C and has a volatile matter content of 15 to 25 per cent. Carbonisation is self-supporting for heat, if properly done.

Charcoal is still being made by the crude method of partially burning wood in earth-covered mounds or holes in the ground, or a combination of the two. This method has many drawbacks. The charcoal produced is uneven in quality, burns smokily, has a high water content and acidity, and is often contaminated with impurities. By-products such as pyroligneous acid and tar are also not recovered. Pyroligneous acid used to be a major source of methanol, acetone and acetic acid; with increasing prices of petroleum and dwindling resources of oil, recovery of chemicals like methanol from wood distillation may become economic once again when done on a large scale. Certain wood tars provide the starting material for disinfectants, pesticides and wood preservatives.

The operational difficulties of pit kilns were overcome by using brick kilns which, however, are costly and the wood has to be brought to the plant. Rectangular kilns with one to five-cord capacity were constructed. One cord measures 2.4 x 12 x 1.2m. Portable sheet steel kilns were also tried. A kiln with a diameter of 7.1 m at the base and 1.2 m. at the top and 1.5 m tall can handle one cord. Such kilns are portable and are, therefore, being used in some of the less developed countries. The Tropical Products Institute (UK) uses a portable steel kiln which can yield 750 kg charcoal; each run takes two days.

Many processes have been developed for the carbonisation of wood with by-product recovery. Only a few are in commercial practice. The processes can be classified as (1) externally heated (2) internally heated, (3) batch and (4) continuous processes.

Externally heated processes

In the early designs with recovery of by-products, part of the wood was allowed to burn to furnish the heat for

[illegible]

[illegible]	[illegible]	[illegible]	[illegible] (mt or)	[illegible] (%)	[illegible] (%)
1982-83	255.7	51.6	204.1	20.2	79.8
1987-88	276.1	73.3	202.8	26.5	73.5
1992-93	296.4	100.6	195.8	33.9	66.1
2000-01	329.0	165.5	163.5	50.3	49.7

carbonisation. The next development was use of small externally heated retorts of 1.5m diameter and 2.7 m length. Two such retorts were set in a fire box. Charging and discharging was manual. This was further simplified in the French can method in which metal containers with wood were lowered into the fire box and later removed when carbonisation was over, and allowed to cool. Another container was lowered into the fire box. In a modern retort, wood is distilled in steel cans called "buggies" in long horizontal ovens. Each buggie can hold 2.5 cords of wood. A retort holding four "buggies" is common. Wood tar was commonly used for firing these retorts. For wood containing high moisture, pre-driers were added, using flue gases to dry the wood. Charcoal coolers were also provided. Wood was processed into 1.3m or 25—38 cm pieces. The normal distillation cycle was 24 hours. This oven process has disadvantages like a large temperature difference between the top and the bottom (100°—200°C) heat losses in removal of buggies and lack of accurate control.

Internally heated processes are thermally more efficient and can be built in larger capacity. The batch-type Reichert process uses the principle of gas recirculation. The retort is 5 m in diameter and 8.5 m high. Wood (0.3 m long pieces) is fed to the retort and oxygen-free gas heated to the required temperature in a gas heater flows from top to bottom at the rate of 0.1—0.3 m³/hr/kg of wood. Cracking of carbonisation products is avoided by removing them quickly from the retort. This also avoids condensation of tar and other products near the discharge end. When the temperature of the outlet gases reaches 200°C, carbonisation is considered complete and the residue is discharged into air-tight bunkers and cooled. Carbonisation takes 20 hours and filling and emptying the retort takes 10 hours.

Continuous processes

Among the continuous processes, the Lambiotte process uses a vertical cylindrical retort to carbonise wood pieces. The retort is heated by inert gases produced in a combustion chamber. Pre-dried wood is continuously fed at the top and charcoal discharged at the bottom. Hot gases are introduced half-way in the retort. A portion of the circulating gases is fed at the bottom to cool the charcoal. The process does not require additional fuel unless the moisture content in wood exceeds 25 per cent. A retort 2 m in diameter and 5 m high can carbonise 1 t wood/hour. This process is reported to give higher yields of acetic acid and, methanol than the oven method.

The Regional Research Laboratory, Hyderabad, has also developed a continuous process for carbonisation of wood with internal heating system. Pieces of wood move slowly from top to bottom, get first dried and then carbonised, and in the lower section the charcoal is cooled with cold gas before discharge. Products of carbonisation are withdrawn through a dust separator and a tar separator by a fan and fed to the condenser. The non-condensable gases are fed to the combustion chamber in the carboniser section and also to the cooling section to cool the hot charcoal. The carboniser is initially brought to the operating temperature with an external fuel and after this no external fuel is required. Wood pieces of 5 cm × 5 cm × 10 cm are processed. A 50 t/day plant based on this process for carbonisation of pine wood has been set up in Himachal Pradesh. This plant is based on the internally heated system and is meant for processing pine wood pieces. It has a by-product recovery system. The pine tar after separation from the aqueous liquors is sold to rubber industries. Wood has, however, to be cut to a size of 50 x 50 x 100 mm, which results in production of saw-dust.

The Badger-Stratford process uses exothermic heat of carbonisation. Wood pieces 20 x 10 x 2.25 cm are fed to a hot carboniser and the heat of carbonisation is enough to bring the fresh charge to the decomposition temperature. A thick layer of charcoal is maintained at the bottom of the retort and partly cooled charcoal is withdrawn from the bottom. The retort is cooled once in two weeks and any tar condensed on the walls is burnt. This process is specially suited for chopped or hogged waste.

In all the processes mentioned above, wood has to be cut into small pieces, which increases the cost and produces saw dust as a waste product. To overcome such difficulty, a tunnel kiln (100 m long) has been suggested. This has five compartments. Wood travels through an initial charging section, a drier (38 m long), a carboniser (26 m long), a cooling section (20 m long) and finally a discharging section. These compartments are separated by hanging doors. The carboniser section has a combustion chamber attached to it. The volatile products are condensed and the non-condensable portion is burnt in this combustion chamber and the combustion products are circulated in the carboniser section. A portion of the gas is fed to the cooling chamber and then to the combustion chamber. This process, though attractive, has not been proved commercially useful. Big logs placed in trolleys moving on rails are used in this process. This method, however, introduces difficulties in pre-drying wood. Steam from the central portion of wood escaping through the hot outer zone causes rapid shattering of the charcoal. Split or band-sawed blocks give a good product.

The cost of production of charcoal depends on various factors like capacity of the plant, recovery and processing of by-products and the returnsfrom the by-products. No data are available on the cost of production.

The yield of products in carbonisation is as follows. The charcoal yield is 35—40 per cent on oven-dry wood Pyroligneous liquor, the major by-product, has methanol and acetic acid as important constituents. Depending upon the process, composition and moisture content of wood, the yield of pyroligneous liquor varies from 300 to 800 kg per tonne of wood. Wood tar is of two types. One is the soluble or dissolved tar, which is soluble in pyroligneous liquor and separates during refining and the other is the settled tar which is insoluble in liquor and is heavier. The former is a mixture of complex compounds. The total yield of tar is 12—13 per cent. Pyroligneous liquor contains 11 per cent acetic acid and homologues, 3 per cent wood spirit, 7 per cent dissolved tar and 79 per cent water. By slow distillation, wood spirit boiling up to 80°C is removed; thereby the solubility of tar in liquor is reduced. The distillate contains 60-70 per cent wood spirit constituents, 10-15 per cent acetone, 10-15 per cent methyl acetate and some other minor constitutents. Multi-column distillation units are used to

(Continued on page 64)

The latest Jaguar International, in service with the Indian Air Force, is an even more powerful version of the aircraft which has proved in service with the Royal Air Force in Britain and Germany, with L'Armée de l'Air in France and overseas, and with the air forces of Ecuador and Oman, that it provides the versatile, cost-effective weapon system essential to meet tactical defence requirements throughout the 1980s and 1990s.

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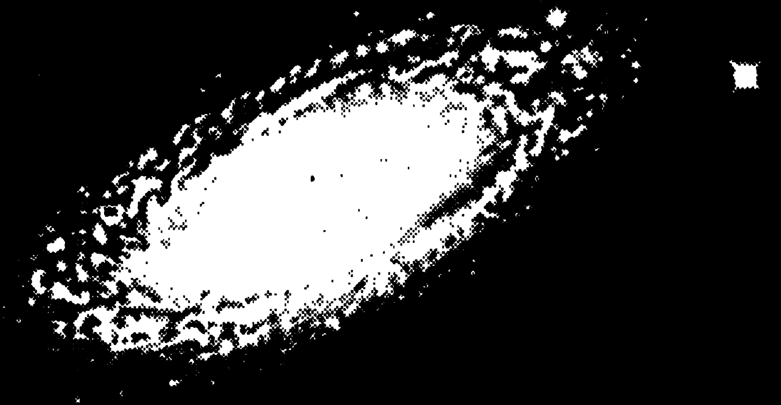
FROM THE INFINITE



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BOOKS

Three fetschrifts for the environmentalists

A Bundle of Feathers—proffered to Salim Ali, ed. by S. Dillon Ripley, Oxford University Press, Delhi, 1978, 241 pp, Rs. 85.

Glimpses of Ecology, R. Misra Commemoration Volume, ed. by J. S. Singh and B. Gopal, International Scientific Publications, Jaipur, 1978, 592 pp, Rs. 300.

Management of Environment, A. K. Ganguly Felicitation Volume, ed. by B. Patel, Wiley Eastern, New Delhi, 1980, 578 pp, Rs. 240.

MY DAUGHTER studies in a central school. A couple of years ago, she used to study science and social studies. And then, suddenly, she was studying environmental studies I and II. Science and social studies had vanished; environmental sciences had come of age. Not that there was any change in the content of the textbooks. The labels had merely metamorphosed—a part of the bandwagon effect. With the establishment of a Department of Environment at the Centre and in some states as well, the bandwagon will now inevitably gather momentum.

Much before the bandwagon started rolling, there were solid scientific efforts in the field of environment in India. And these were primarily the work of three men: Salim Ali, Ramdeo Misra and Anil Kumar Ganguly. They were born roughly ten years apart from each other—Salim Ali in 1896, Misra in 1908 and Ganguly in 1918.

Salim Ali, the famous bird-man of India, devoted his entire life to the scientific study of birds which culminated in the monumental, ten-volume *Handbook of Birds of India and Pakistan*. Misra, a botanist, was the earliest to turn to plant ecology and established a solid school of studies on plant productivity at Banaras Hindu University. Ganguly, a chemist, was drawn to the study of radiation hazards of nuclear power plants and, working at the Bhabha Atomic Research Centre, he developed a whole range of activities relating not only to radiation but other problems of chemical pollution and aquatic environments. All three having reached venerable ages, the last three years have seen the publication of three felicitation volumes to these pioneers.

The three volumes, carrying over a hundred articles, make a most interesting set. They give us a fair idea of the present state of environmental sciences not only in India but in the world, for many distinguished scientists from abroad have also contributed to these volumes.

A Bundle of Feathers reflects our concern with conserving wilderness and the sheer pleasure of watching the fascinating creatures that are birds. It includes articles tracing how the changing pattern of land use in Soviet Central Asia has led to a gradual shrinkage of the range of the Great Bustard and a speculative review of what leads to the expansion of ranges of birds such as the Ring Dove that has recently invaded Europe. It carries a fascinating account of how the hill mynas develop their complex repertoire of songs by imitating their neighbours, but always of the same sex, so that the males and females have songs overlapping within the sex, but quite distinct across the sexes.

Glimpses of Ecology reflects concern not so much for wilderness, but for sustaining the productivity of the land. The mainspring of the work reported in this volume is the International Biological Programme of UNESCO. This programme promoted a whole series of comparative studies on production and dynamics of ecosystems, many of which are reported here. There are reports on plant production in the dry Arvallis of Rajasthan, in the oak forests of Nainital, heath forests of Indonesia and the rain forests of Amazon. There are useful reviews of problems of grazing in forests and grasslands and the management of such lands, of the role of earthworms in the decomposition of organic material and of "allelopathic" chemicals in determining plant succession. The significance of ecological principles for managing the affairs of mankind are discussed.

Management of Environment is primarily concerned with technologists' preoccupation with alleviating the poisoning of the land and the air and the waters around us. The emphasis is on pollution through radioactive material and chemical pollution, particularly of the waters. But there are also a number of other papers on topics ranging from meteorological models of dispersion of pollutants from a high chimney to the study of prehistoric environments from archaeological sites.

Taken together, this set of three books tells us pretty much what is going on, and not going on, in environmental sciences in India. But it doesn't have enough of careful and authoritative reviews of the state of environment in India today; this is something one might have expected of these books. Perhaps, this is something we have to wait a little longer for.

MADHAV GADGIL

Prof. Gadgil is with the Centre for Theoretical Studies, Indian Institute of Science, Bangalore.

Computers and systems analysis

Systems analysis and data processing by A. Subramanyam and K. S. Menon, A. H Wheeler and Co Pvt Ltd, Allahabad, 1979, 235 pp, Rs 50

THE BOOK, in two parts, gives an adequate theoretical background about computers and systems analysis. The 19 topics in the book are well analysed and presented in a processed output.

The systems analysis part explains the six steps involved in systems analysis and their interrelations through a flow chart, with checkpoints introduced at various steps. It discusses techniques of systems analysis, such as fact-gathering methods, flow-charting with symbols, decision tables and simulation, the sources and methods of computer inputs, output designs, types of outputs, forms designs, types of files, etc.

Information system, which is a part of data processing, is well elucidated in the second part, comparing manual and machine systems. The example explained projects a clear picture of an information system. Besides describing the various data processing systems, the section also discusses classification of storage in computers, comparison of various storage systems, computer softwares, output devices as line printers and video display units, management of data processing and data security.

The two data processing systems prevalent in India are Unit Record Machine System and Electronic Computer System. One can get a clear idea of a punched card and its designs with various elements, method of transferring information and the functions of reproducer and sorter. Other topics cover the principles involved in coding a system and the representation alphabet and numbers and special characters, followed by illustration of the classification of electronic computers such as analog, digital and hybrid, types of input media, and their description with suitable photographs.

P. PARAMASIVAM

Mr. Paramasivam is maintenance engineer at the Nehru Planetarium, Bombay.

What's new on Saturn?

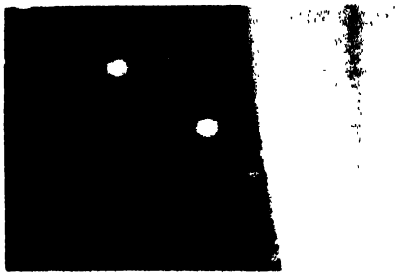
The weather has not changed much over the past nine months but the number of rings has greatly multiplied

ITS mysteries seem to deepen with every new encounter. Voyager-2, following Voyager 1 (which flew past the ringed planet nine months ago) tried to check its predecessor's findings while scanning for new info.

In the beginning, it was thought that the planet had only one ring around it: then it came about that it wasn't just one ring but a system of three divided by dark spaces in between. The Pioneer and subsequent missions found more rings, now totalling seven (labelled A to G) and the latest indications are that the rings are a system of thousands of ringlets.

Voyager 2 discovered a new kinky ring in place where no ring was expected in a dark gap—the Encke division. Faint, five-stranded and closely kinked, the ring did not have the expected attendant shepherd moons

The ringlets were counted by photopolarimetric measurement of the light of a star being occulted by the system. Within the Encke gap itself, 10 dips were recorded in the light curve. The actual ringlets, according to Larry Esposito, University of Colorado, USA, extend "maybe down to the individual particle size". To cause so many divisions in the rings, surely there must be many moonlets—so astronomers had figured (SCIENCE TODAY, November 1979). But none were found. The cause of the gaps and the fine structure of the rings thus remains a mystery.

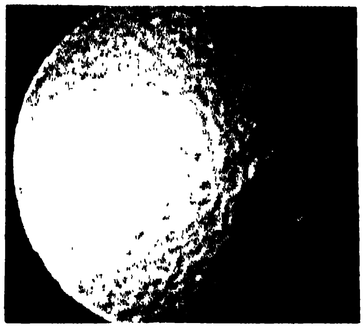


The sheep dog satellites guarding the F-ring. The bright disc at the right is the A-ring. The F-ring showed up as composed of five smooth concentric circles. The kinks and braiding that Voyager 1 noticed could not be seen

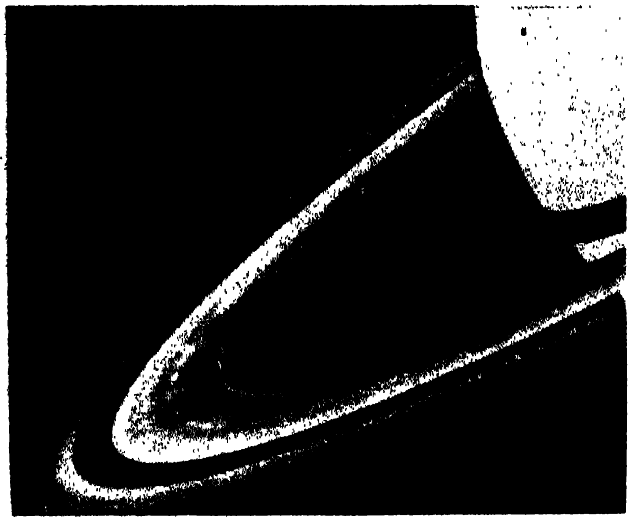
Voyager 1 had found the F-ring consisting of three strands to have a braided structure. However, the portions which Voyager 2 photographed presented a smooth concentric structure suggesting that the braiding occurs only in some regions of the ring.

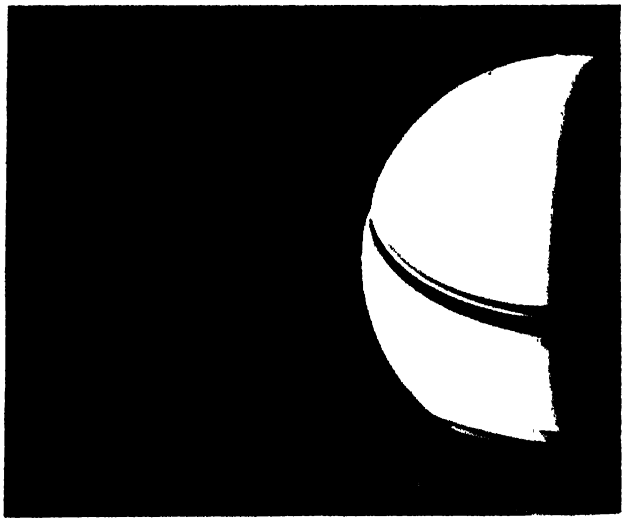
Voyager 2 also had a minor mishap: in its trajectory, even after passing through the ring plane outside the G-ring on the far-side of the planet, its scan platform got jammed. The same path had been taken earlier by Pioneer 11 and Voyager 1. The mission scientists figure that a stray particle—whatever its source—caught in the platform's gears may have been responsible for the wrecking. The jamming was, however, slowly released. Hopefully it will now relay new data from Uranus in January 1986.

Meanwhile, theories about the formation rings abound. Whether they are particles that failed to coalesce and form a satellite or they are a single body that broke up is not clear. The three main rings, A, B and C, show distinct characteristics. This would imply that they could be the debris of three different objects.



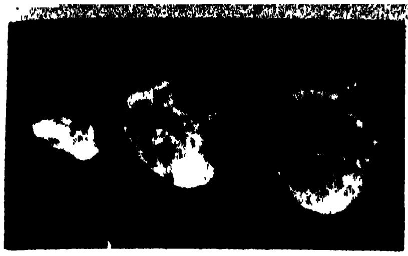
Tethys showing a 400-km wide impact crater





The mystery of the spokes (above left) have yet to be resolved. A time-lapse movie following a group of spokes showed that new spokes form quickly as old ones fade. What is surprising is the speed with which they leap across the ring surface—within 12 minutes they cover a distance of 20,000 km. Several theories have been put forward explaining the formation of spokes: 1) they are said to be caused by the planet's magnetic field, 2) they could be due to the ionisation of dusty material in the ring by sunlight and these spokes of ionised particles are elevated from the ring plane by the planet's magnetic field and 3) another exciting theory relates to the periodicity of electrical discharges from Saturn which matches the orbital speed of the B-ring where the rings are most prominent and, therefore, the theory holds that spokes are linked to the discharges. Only a detailed analysis of the Voyager data will give a clearer picture.

The details and differences in the ring-system (above right). The "reddening" of the B-ring on the unlit side also was seen in Voyager 1 images. Voyager 2 obtained this picture from a range 3.4 million km through the clear, green and violet filters

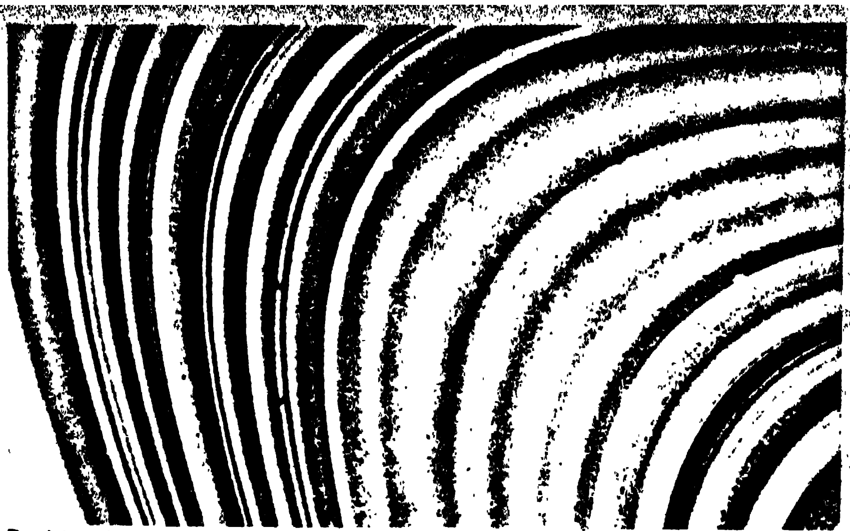


Hyperion, the strangely tilted moon, showed up as an oblate disc. Its rotation axis is at an angle to its short axis

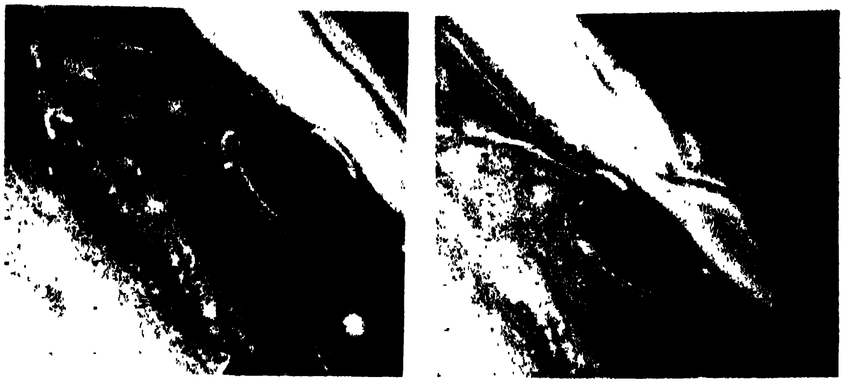
The planet's weather was found to have changed somewhat over the past nine months—the equivalent of a week in the 30-year Saturn year. Storms on Saturn, like those on Jupiter, are long lasting, though there have been some minor changes—huge irregular storm systems have changed shape and one large white one has lost its dark edges.

The Saturnian family of satellites is, on the whole, icier, whiter and colder than the Jovian family. The polar hood of the Titan, photographed by Voyager 1, has evolved into a collar. Tethys sports a 400-km wide crater. And Mimas, according to earlier missions, has an extra large crater (SCIENCE TODAY, February 1981 p 42). But the whole of Mimas would fit into Tethys's crater. Considering its size, however, Mimas has had a more severe impact. The black and white Iapetus, Voyager 2 found, had starkly contrasting surfaces—the trailing hemisphere was 15 times brighter than the leading one. Earth-based calculations had put it as only five times brighter. The reflective properties of the pitch black end probably exactly match that of pitch. On Iapetus there is enough carbon in the form of methane.

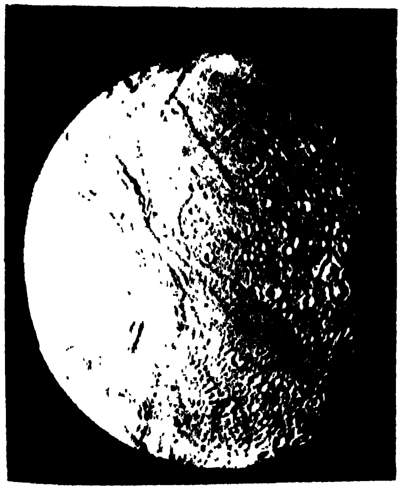
Many of Saturn's satellites are not spherical. Most peculiar of these



Ringlets within ringlets. Viewed close-up from Voyager 2, the ring system appears like a phonograph record Rings come in many variations; thick, thin, bright, tenuous concentric, elliptical, etc. Where the imaging shows thousands of rings, photopolarimetry revealed hundreds of thousands. Often, in ringlets, fine particles are denser at the edges than in the centre

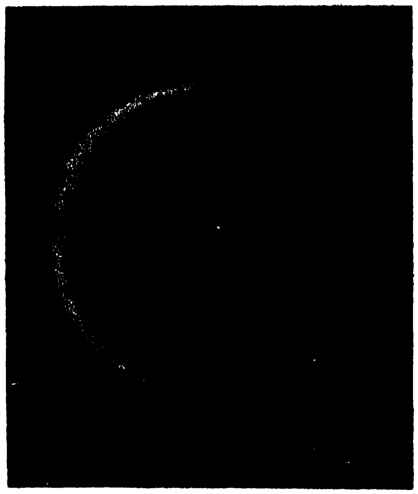


Circulation around a large brown spot in Saturn's atmosphere can be seen in this pair of green-filter Voyager 2 images taken Aug 23 and 24 from distances of 2.7 million and 2.3 million km respectively. The left frame was taken about 10 hours 15 minutes before that at right. Brighter clouds like that seen to the north-west of the spot (to the upper left in these views) are observed in this time-lapse comparison to move in an anti-cyclonic direction (counterclockwise in the northern hemisphere). One interpretation says this anti-cyclonic motion is associated with downdrafts that would induce clearing over the spot. Consequently, the spot itself may represent an opening in Saturn's upper cloud deck through which darker underlying clouds can be seen. The smallest features visible here are more than 50 km



Enceladus, the third moon of Saturn, photographed in saturnshine on 25 August, from a distance of 110,000 km. About 600 km in diameter, it resembles Jupiter's Galilean satellite, Ganymede, which is 10 times larger

Iapetus has two distinct faces—a black one and a white. The dark, leading face is thought to be composed of carbonaceous material that has been exposed due to bombardment of particles from Phoebe



Titan—the only satellite in the solar system that has an atmosphere—viewed from the night side. Clearly visible is the atmosphere, due to scattered sunlight, topped by a haze of submicroscopic particles is the oblong satellite Hyperion; it seems to be unsteadily rotating at a strange angle instead of on its short axis as a stable object should.

Saturn's radio emissions were so powerful that they could be detected 600 million km away. But for some reason, for four days Saturn turned off its radio emissions. Voyager I had shown that the northern hemisphere was a stronger emitter. Only for a short while during those four days, when the spacecraft crossed the ring plane was it blocked from the northern hemisphere. Scientists are still debating the causes. Meanwhile, bow-shock tail which was estimated at 35 Rs (Saturn radii) found to extend to 87 Rs. The solar wind during the Voyager encounter may have been weak, is the explanation scientists offer for the long tail.

One highlight of the present encounter was to study the effect of Jupiter's magnetic tail on Saturn. If it were strong, the Voyager 2 would not have encountered a bow-shock. However, it did, implying that Jupiter's tail must have been elsewhere during the encounter.

Fredrick Scraf who measured the oscillations of the electrically charged plasma caught some frequencies audible to the human ear; he played back the sounds of Saturn on a conventional loudspeaker; it was an eerie whistling music with some hisses and pops. The bow-shock sounds like waves breaking on a beach. Scraf and colleagues divided the data into 16 frequency channels and played it through a 16-channel music synthesiser. What emerged was a minute-long slow dreamy mild level basses surging and ebbing against a deep roll of basses and a high floating treble.

There will be a deep lull following this hectic activity. Mission scientists have plenty of time to study their data till the Voyager reaches the next planet since no new planetary missions have been planned.

A composite of seven very small satellites of Saturn as photographed Aug 25 by Voyager 2. These irregularly shaped bodies have been highly cratered by the impact of cosmic debris. The irregularity is probably due to fracturing by large impacts and is sustained by the rigidity of the bodies. The lighting angles and ranges here are different for each satellite; thus, true relative sizes are not shown. These objects range from about 10 to several hundred kilometres across

SUMATI SAMPEMANE

Miss Sampemane is on the editorial staff of SCIENCE TODAY

(Continued from page 57)

CHARCOAL

separate methyl alcohol. The yield of methanol is 1–2 per cent on dry wood.

Acetic acid was earlier recovered by absorbing the acid vapours in lime and subsequently treating with acid to liberate acid from calcium acetate. The yield of acetic acid is 4 per cent in dry wood. In modern processes, an acetic ester or ethyl ether is used to extract the acetic acid in a counter-current manner. The extract is distilled under vacuum to get raw acid which is processed for removal of other acids like propionic and butyric. Azeotropic distillation with butyl acetate or a specific fraction of wood spirit has also been suggested.

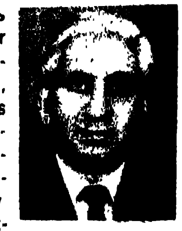
The tar is used as fuel or distilled to get fractions which can be used as flotation oil, disinfectants, preservatives, etc. It has a calorific value of about 5,800 K.cal/kg. It degrades fast when heated and is also corrosive.

The gas from carbonisation has a calorific value of 2000 to 3000 K.cal/Nm^3 with the following composition per cent carbon dioxide, 45-55; carbon monoxide, 28-35; methane, 3.5-10; hydrogen, 1-5; and ethylene, 0-2. This gas can be used as a low calorific value fuel to replace furnace oil. The yield of gas depends upon the carbonisation process.

Recovery of chemicals involves complex processing steps. With the prevailing petroleum prices, recovery may be economic if done on a large scale. In smaller units, the pyroligneous liquor and tar may pose disposal problems. Under such circumstances, it may be better to burn the entire volatile products, including liquor and gas, to generate power. Roughly, from a 250 t/day plant, about 10 MW can be generated by burning all the volatile products. The volatile products can also be subjected to further cracking to improve the yield of gaseous products. Both these alternatives are worth considering when the recovery of chemicals is uneconomic.

In conclusion, wood carbonisation as an industry offers good scope for the production of charcoal for use as domestic fuel, or in the chemical industry, or for the production of activated carbons. The by-product can be processed for the recovery of methanol, acetone, acetic acid, depending upon the quantity produced. Alternatively, the volatile products can be burnt and power generated. It is necessary simultaneously to plan for large-scale afforestation.

Mr. Rao is Assistant Director, Regional Research Laboratory, Hyderabad. He took his M.Sc. from the Osmania University in 1952. In 1963-65 he underwent advanced training in coal technology in West Germany. His major activities have been in the utilisation of low-grade coals, wood carbonisation and the processing of saw dust and agro-wastes.



Dr. Vaidyeswaran is Scientist (Director Scale), Regional Research Laboratory, Hyderabad. He took his Doktor Ingenieur degree from the Technische Hochschule, Karlsruche, West Germany He has specialised experience of utilisation of low-grade coal for energy and chemicals. Among the research projects he has handled are: low temperature carbonisation for the production of solid domestic fuel; briquetting of char fines, coke breeze, charcoal fines, etc, for the production of domestic fuel, and complete gasification of coal. He has been convenor of an expert panel on "Coal Utilisation for Import Substitution in Energy Sector"

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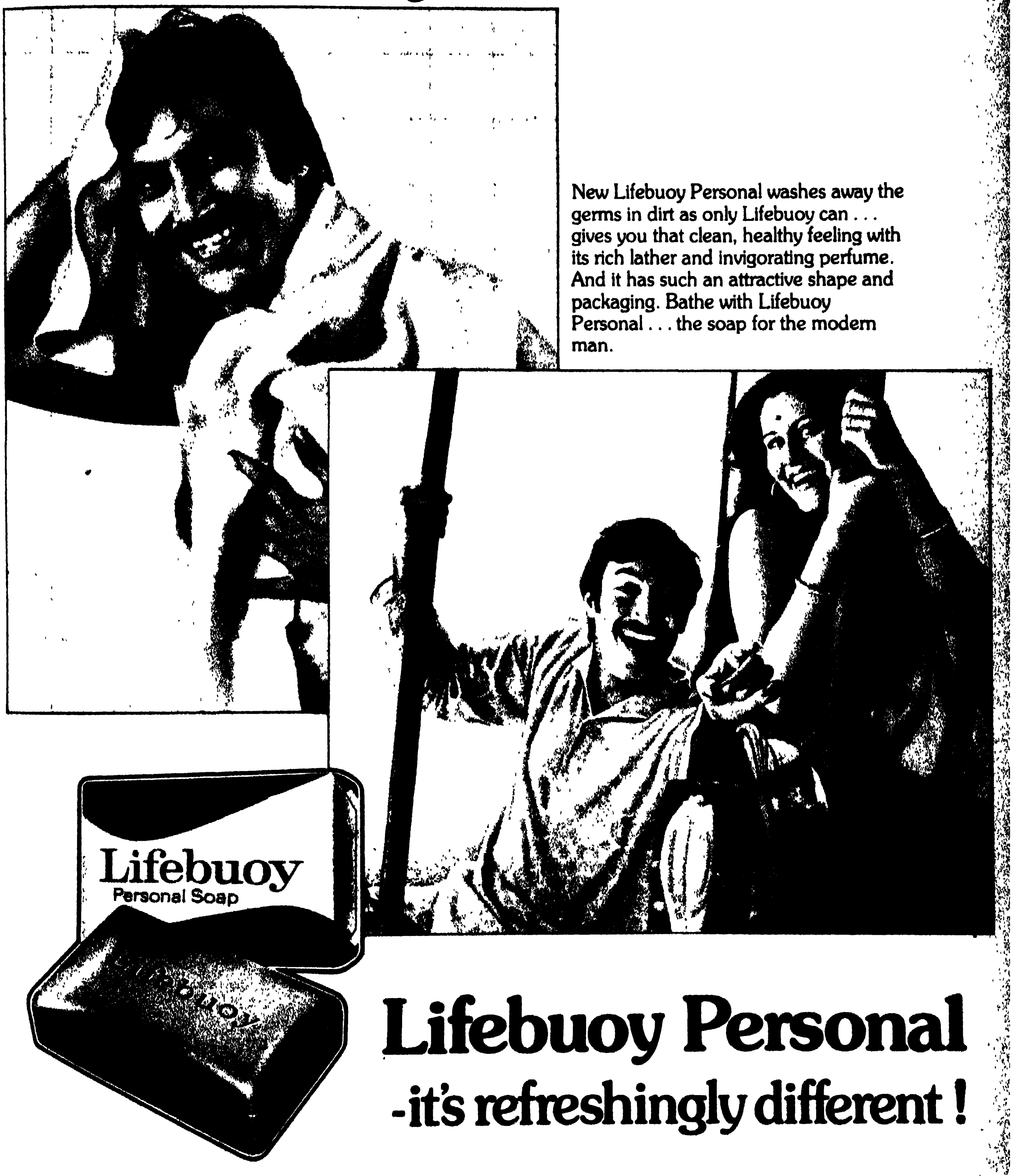

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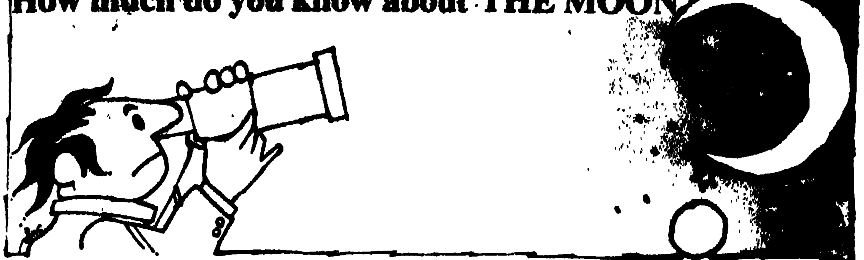
How much do you know about THE MOON



Myths and lore about the Moon are countless. Though no longer out of reach, a lot of its secrets are yet to be unravelled. The Moon affects the Earth in several ways. How? Listed below are 15 questions and with three probable answers. For the correct answers turn overleaf.

1. The mean distance of the Moon from the Earth is about: A. 40,000. B. 400,000. C. 4,000,000 km.

2. The Moon does not have an atmosphere due to its low escape velocity, which is about: A. 2km/sec. B. 5 km/sec. C. 10 km/sec.

3. The Moon goes round the Earth once in a month. There are two lunar months, defined as the siderereal month and synodic month. The sidereal month is: A. about 2 days shorter than the synodic month. B. two days longer than the synodic month. C. the same as synodic month.

4. The lunar rocks differ in chemistry from terrestrial rocks. An element which is enriched is: A. Gold B. Silver C. Titanium.

5. What is the Harvest Moon? A. The Moon seen during an eclipse. B. The Full Moon near the autumnal equinox. C. The crescent Moon.

6. The maximum daytime temperature on the surface of the Moon is: A. 75°C B. 135°C. C. 475°C.

7. The Moon and the Sun appear to be nearly of the same size in the sky. The angular diameter of the Moon is: A. 10 arc minutes. B. 30 arc minutes. C. 1 degree of arc.

8. The average density of rocks on the surface of Moon is: A. equal to, B. more than, C less than the mean density of the Moon.

9. What is libration? A. The Moon coming out of the solar disc after a total eclipse. B. The surface areas of Moon which are seen in excess of 50 per cent. C The volcanic explosions on the Moon.

10. The Moon causes tides on the ocean. What are spring tides? A. Tides that occur during spring. B. Tides that occur in summer. C. Tides on Full Moon and New Moon days.

11. The centre of mass of the Earth-Moon system is situated at about: A. 1600 km below the Earth's surface. B. 3600 km above the Earth's surface. C. 1000 km above the centre of the Earth.

12. What is lunar occultation? A. The passage of the Moon between the Earth and a star. B. Shadows of high mountains on the lunar surface. C. Superstitions associated with the Moon.

13. The distance between the Earth and the Moon has not always been what it is today. The Moon: A. is coming towards the Earth. B. is going away from the Earth. C. oscillates.

14. Even during a total lunar eclipse, the Moon does not completely vanish from our sight. It looks dimly red due to: A. the glow of hot rocks on Moon emitting dim light. B. light scattered by Earth's atmosphere falling on the Moon. C. light reflected from the surface of the Earth.

15. What is a "gibbous Moon"? A. Phase of the Moon between New Moon and first quarter. B. Phase of the Moon between third quarter and New Moon. C. Phase which is more than a semicircle.

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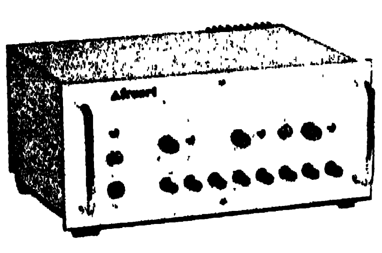

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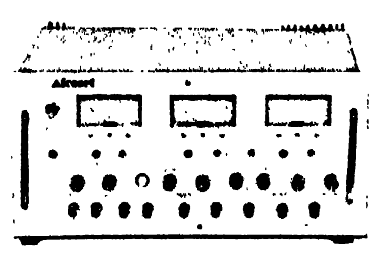

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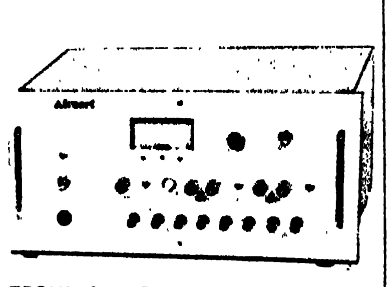

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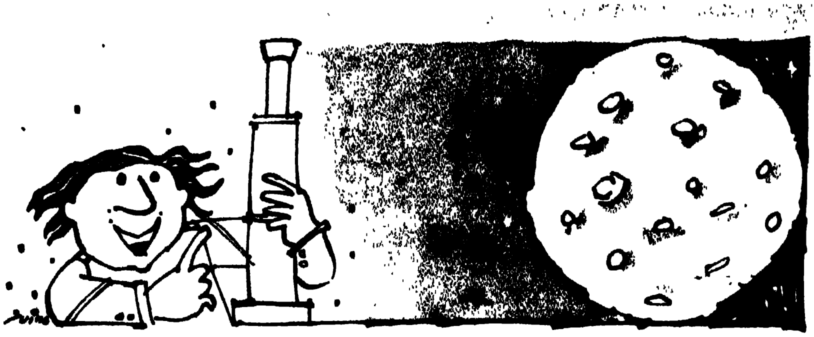
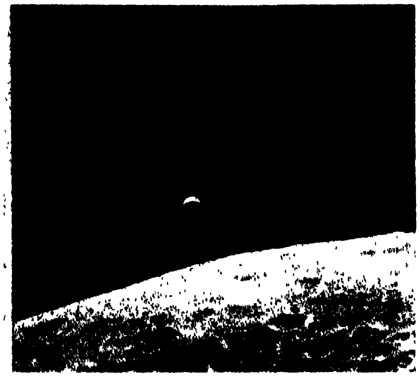
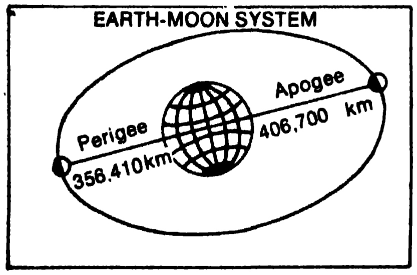


The Answers



Crescent Earth as seen from the Moon



1.—B: Due to the elliptical nature of the Moon's orbit around the Earth, the Earth-Moon distance varies from 356,410 km (shortest distance or perigee) to 406,700 km (longest distance, or apogee) and the mean is 384,402 km from the centre of the Earth to the centre of the Moon.

2.—A: The escape velocity at the surface of a planet depends on the mass and radius of the planet. For the Earth it is about 11 km per sec. For the Moon the escape velocity is 2.36 km per sec. The escape velocity on the Jupiter, for example, is 60.22 km per sec.

3.—A: The Moon takes about 29.5 days to go around the Earth, if the Sun is used as a reference point. This is the period between one Full Moon and the next and is called the *synodic month*. When the distant stars are used as reference points, the Moon completes one revolution around the Earth in about 27.33 days which is called a *sidereal month*.

4.—C: A detailed chemical composition study of Basaltic rocks from the surface of Moon points out that the elements like titanium, iron and magnesium are enriched compared to terrestrial rocks whereas elements like gold and silver are depleted. A new mineral—opaque oxide of iron titanium and magnesium similar to ilmenite—was found on Moon. This is named Armalcolite after the astronauts Armstrong, Aldrin and Collins. Titanium occurs upto about 10 per cent in lunar basalts compared to about 2 per cent on terrestrial basalts. In general the volatile elements are depleted and high temperature mineral-forming elements are enriched. This points to the fact that the matter which went to form the Moon got separated with a higher temperature condensate accreting first. It also shows that the Moon was never a part of the Earth. It may have been formed in a nearby region or may have been captured much later by the Earth.

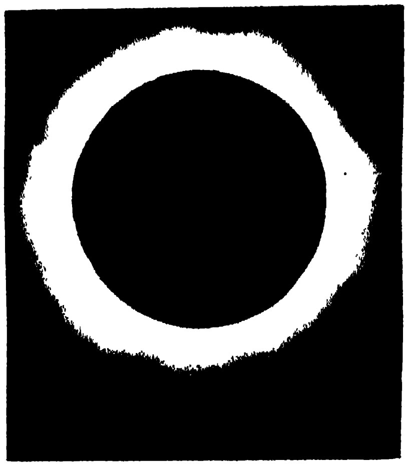
Lunar rock under microscope. The dark areas are due to the titanium-rich mineral, Armalcolite.

5.—B: The Moon's apparent eastward motion in the sky makes it rise on an average 51 minutes later every day. During the month of September, instead of rising 51 minutes late, Moon rises only 10 minutes late every day in mid latitudes. At autumnal equinox, the Sun moves towards the south at its maximum rate and the Full Moon therefore moves northward at its maximum rate. This northward motion partly counteracts the Moon's tendency to rise late. A nearly-Full Moon will appear shortly after sunrise for many days which helps the farmer's harvesting with extended light. Hence the name "Harvest Moon". In the southern hemisphere the Harvest Moon occurs in March around the time of our vernal equinox.

6.—B: Since the Moon does not have an atmosphere, the surface gets heated up fast and during daytime it may go up as high as 135°C. However, in the night it gets cooled quickly to -170°C. Even during the day areas on the Moon in the shadows of high mountains and boulders are at temperatures less than the freezing point of ice.

Due the lack of atmoshere, the sky seen from Moon appears dark even during the day and a Moon-based observer can see the stars even at high noon. There is a greater contrast between the lighted and shadowed regions and the temperature in the shade is as much as 305°C cooler than in the sunny region. Such a vast difference is unthinkable on Earth

7.—B: The Moon's diameter is 3,476 km, which is only 1/400 that of the Sun. Since the Sun is also 400 times farther from the Earth, both the Sun and the Moon appear to have the same size of about 30 minutes of arc when viewed from Earth. This chance coincidence is responsible for the total solar eclipses.

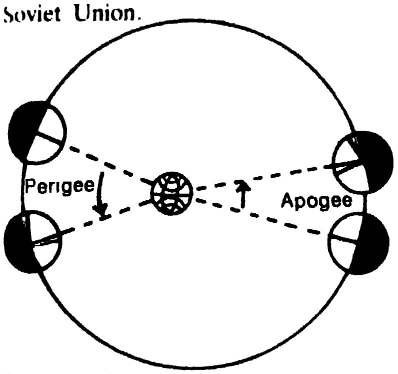


Bhonsle-Degonkar PRL, Ahmedabad

8.—A: The density of rocks on the surface compared to the mean density of a planetary object gives some information about the internal structure of the planet. The rocks on the surface of the Earth are generally of a lower density than that of the Moon. The rocks of Moon have a density which is equal to the average density of the Moon itself (3.34

gms per cc.) The average density of Earth is about 5.5 and the rocks on its surface have a density around 2 to 3. This indicates that the core of the Moon may not be enriched in heavy elements whereas the core of the Earth must contain heavier elements to make the average density of 5.5.

9.—B: Due to the fact that the period of its revolution around the Earth and its axial rotation period are the same, the Moon always shows the same face to us. However, during each lunar month we can see about nine per cent more of its surface because of slight changes in its orientation towards the Earth. These apparent tilting motions are called librations. The entire far side of the Moon was first seen by the *Luna* mission of the Soviet Union.



The shaded areas come into view alternately as the Moon apparently wobbles in its orbit around the Earth

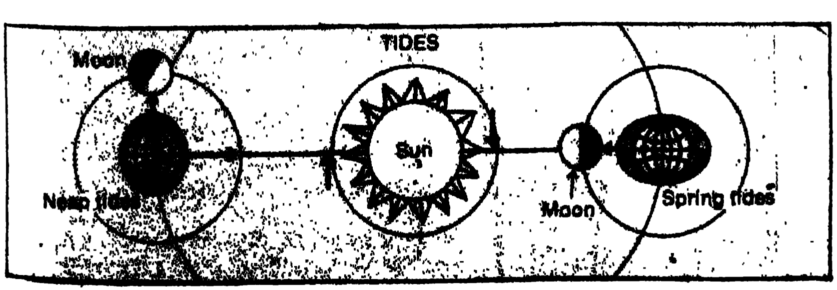
The far side of the Moon is more uniformly cratered than the side facing Earth. Those expansive "seas" or mares are characteristic of the Earth-facing side

10.—C: Even though the tides are mainly caused by the pull of the Moon, the Sun also contributes to the tidal force. During Full Moon and New Moon days, the Sun acts in the same direction as the Moon and this gives rise to higher tides than normal (both high and low). These are called spring tides. During first and third quarters of the Moon, the Sun is in a perpendicular direction (and acts opposite to the Moon) giving rise to a high tide of smaller than normal amplitude—this is the neap tide.

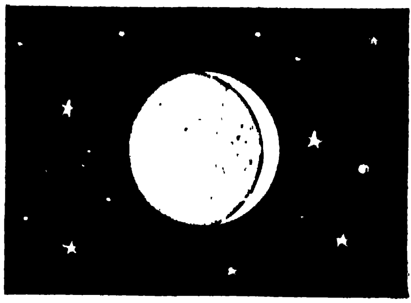
11.—A: The centre of mass of the system of two objects lies nearer to the heavier object. If the secondary object's mass is very small, the centre of mass of the system essentially lies at the centre of the primary object. In the case of the Moon, it being massive, the centre of mass is situated only about 1,600 km below the Earth's surface. If they were of equal mass and size, the centre of mass would lie equidistant from their centres.

12.—A. When the Moon comes between the Earth and a star, it is called a lunar occultation. Such occultations are astronomically useful for understanding the envelopes of stars. The dimension of the Crab nebula in X-rays and radio waves and its structure could be got in detail during the occultation of the Crab nebula by the Moon. Such an occultation also reveals that the Moon does not have an atmosphere. The star vanishes abruptly when occulted by an atmosphereless object, the presence of an atmosphere is revealed by a gradual dimming.

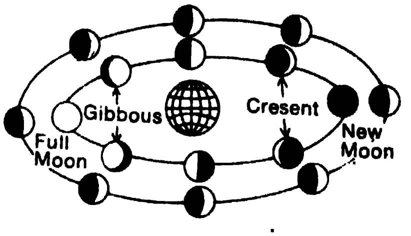
13.—B: From a very accurate measurement of the distance between Earth and Moon (which can be measured with an accuracy of about 10 cm using laser reflectors kept on the surface of the Moon by Apollo astronauts) it is clearly proved that the Moon is receding from the Earth. This is also anticipated from the nature of tidal friction which the Earth-Moon system undergoes. The tides caused by the Moon on the Earth slow down the rotation of the Earth and hence its angular momentum, and the conservation of angular momentum demands that the Moon should go away from the Earth to orbit with a higher angular momentum. In fact, it is believed that the Moon was very close to the Earth some billions of years ago when the day on the Earth was about 10 hours instead of the present 24 hours. The study of the ancient corals also points to the fact that the days in the past were shorter leading to more number of days per year. This fact was found from counting the number of fine rings that are formed in the coral in its annual growth. This fine rings appear once a day due to temperature variations (during day and night) during the growth of the corals. When the Moon goes very far away from Earth, it will appear much smaller and total solar eclipse will not occur; then there will be only partial or annular eclipses.



14.—B: The light that we see during a total lunar eclipse is due to the light refracted by the Earth's atmosphere which falls on the lunar surface. If the Earth had no atmosphere, a total lunar eclipse will really be total—without any light on the lunar surface. The intensity of light falling on the Moon during a total lunar eclipse depends on the weather conditions prevailing on Earth. However this is not the same reason why during its crescent stage, the dark portion of the Moon is still visible. This phenomenon known popularly as the old Moon in the hands of the new is due to Earthshine on the Moon.



Earthshine on Moon is much brighter than moonlight on Earth not merely because Earth is bigger but also because its albedo, that is surface reflectivity, is higher. The faintly visible dark portion of the Moon at its crescent phase immediately after New Moon —commonly known as the old Moon in the hands of the new—is due to Earthshine



The phases of the Moon as seen from Earth (inner circle) as it swings in orbit (outer circle)

15.—C: The shape of the Moon between half and full (greater than semicircle) is called a gibbous Moon. Gibbous meaning convex or protuberant.

V. S. VENKATAVARADAN

This quiz was prepared by Dr. VENKATAVARADAN, Director of the Nehru Planetarium Bombay

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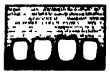

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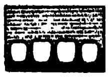

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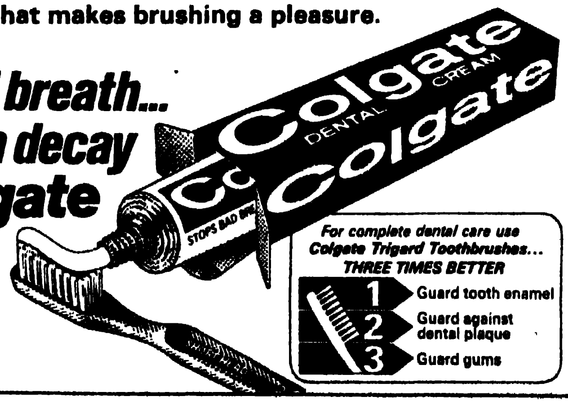

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FUN WITH MATHS

More number sandwiches

KAPREKAR'S gap-filled primes can also be seen as number sandwiches. He breaks a prime into two slices and sandwiches zeroes between the two slices (SCIENCE TODAY, August 1981, p. 39). Below are ten number sandwiches prepared by slicing 11 into two and sandwiching a number which interestingly turns out to be a factor of the number sandwich.

$$1131 = 13 \times 87$$
$$1771 = 77 \times 23$$
$$11371 = 137 \times 83$$
$$10731 = 73 \times 147$$
$$190911 = 9091 \times 21$$
$$1909090911 = 90909091 \times 21$$
$$158823531 = 5882353 \times 27$$
$$1526315791 = 52631579 \times 29$$
$$1769230771 = 76923077 \times 23$$
$$14347826087 1 = 4347826087 \times 23$$

It all depends on selecting which number to sandwich and there is an easy way of selecting it when we make a number sandwich from 11. If the final sandwich is to have n digits, then all we need is that the number be a factor of $(10^{n-1} + 1)$. Of course, if this is to work, $(10^{n-1} + 1)$ must not be a prime. For example, 101 is a prime number. Since 101 has three digits, we won't have our kind of three-digit sandwich from the slices of 11.

What happens when we sandwich a number into the two slices of 11? What we actually do is add 10 times the sandwiched number to $(10^{n-1} + 1)$. Take our first example, $1131 = 1001 + 13 \times 10$. Obviously then, if our number divides $(10^{n-1} + 1)$ then it divides the sandwich.

The number sandwich is obviously related to the gap-filled primes derived from 11. However, some care has to be taken to adjust the digits of the number to be inserted; it must have (n−2) digits. So, add the required number of zeroes to the left-hand side. For example, 73 is a factor of 10001; so while inserting it we add a zero to the left-hand side and the number sandwich is 10731 and not 1731. Our method will also not work when the factor has more than (n−2) digits.

One factor of the number sandwich then is clearly the number we insert, in the above case, 73. What about the other factor? It is the other factor of $(10^{n-1} + 1)$ plus ten. Thus, in the above example, $10001 = 73 \times 137$, so the other factor of the number sandwich is $137 + 10 = 147$.

Incidentally, our seventh sandwich, 158823531, is related to a small error in Kaprekar's piece. 11 gap-filled with seven zeroes, 100000001, is not a prime. It factorises into 5882353×17 and our number sandwich is,

$$158823531 = 5882353 \times 27.$$

K. N. GORDHANDAS

Mr. Gordhandas is a mining engineer in Bombay.

About the peculiarities of 1089

AMONG the four-digit numbers, 1089 has two unique properties (SCIENCE TODAY, September 1981, 69). Firstly, it is the only number which reverses the order of its digits when multiplied by 9. Secondly, it is the only number that satisfies the "same old number property". Take a number and add to it the number formed by reversing its digits. Now take the sum and subtract from it the number formed by reversing the order of its digits. If the result is the same as the original number then it has the "same old number property". Here is a simple proof of the two unique properties.

Let *abcd* be the four-digit number that satisfies this property. Then,

$$abcd \times 9 = dcba \text{ ——— } A$$
$$abcd \times dcba = (abcd)\,(1+9)$$
$$= (abcd) \times 10$$
$$\begin{array}{r} abcd \\ +\,dcba \\ \hline abcd0 \end{array} \text{ ——— } B$$

From A and B we can find the values of *a,b,c* and *d*. Obviously *a* cannot be 0, otherwise the number would become a three-digit number. Also, *a* cannot be equal to or larger than 2 because then $9 \times abcd$, which according to A should be a four-digit number would become a five digit number. So, $a = 1$. By a similar argument we find that *b* must be either 0 or 1.

Let us now consider B. Adding the units place we have $d + a = 10$, so that $d = 9$. Carrying on the addition, the next digit is $d = 9$ so we get $b + c + 1 = 9$ or 19. Since *b* is either 0 or 1, $b + c + 1$ cannot be 19 and we have

$$b + c + 1 = 9 \text{ ——— } C.$$

The next digit in the addition must give the digit *c* so that $b + c = c$ *or* $c + 10$. $b + c$ cannot be $c + 10$ because then $b = 10$. So $b + c = c$ and $b = 0$. Substituting in C, we get $c = 8$. Thus 1, 0, 8 and 9 are the unique values for *a, b, c,* and *d*, respectively, and 1089 is the unique number.

What about the "same old number property"? If we show that a number that satisfies it must reverse its digits when multiplied by 9, then 1089 will naturally be the only four-digit number which has the "same old number property". This can easily be shown.

Let us write the number we get by reversing the digits of a number A as A_{rev}, we must then have,

$$A + A_{rev} = B \text{ ——— } D$$

and $B - B_{rev} = A$,

$$B = A + B_{rev} \text{ ——— } E$$

From D and E we can write

$$A_{rev} = B_{rev} \text{ ——— } F$$

This means that B, the greater of B and A, must be 10 times A. But if $B = 10A = A + A_{rev}$ then $A_{rev} = 9A$, and only 1089 satisfies this relation.

Five-, six- and seven-digit numbers satisfying these two properties can be very simply derived from 1089. Break it into two parts, 10 and 89, and just insert nines between them. 10989, 109989, and 1099989 are the numbers with five, six and seven digits, respectively, which satisfy the two properties.

It is also easy to see why 1089 can be expressed only in one way as the sum and difference of two primes. This is because all primes except 2 are odd. If we have to sum two primes to get an odd number, one of them has to be even, and that can only be 2. Also, if we have to subtract one prime from another to get an odd number, one of them has to be even and must therefore be 2. That is why $1089 = 1087 + 2$ and $1089 = 1091 - 2$.

Incidentally, the three odd numbers involved will have to be consecutive odd numbers, with the non-prime sandwiched between the two primes. And also, precisely for that reason, there are no prime numbers which can be expressed as both the sum and difference of two prime numbers.

D. V. RAMA KRISHNA

Mr. Rama Krishna studies at the Engineering College, Anantapur, Andhra Pradesh.

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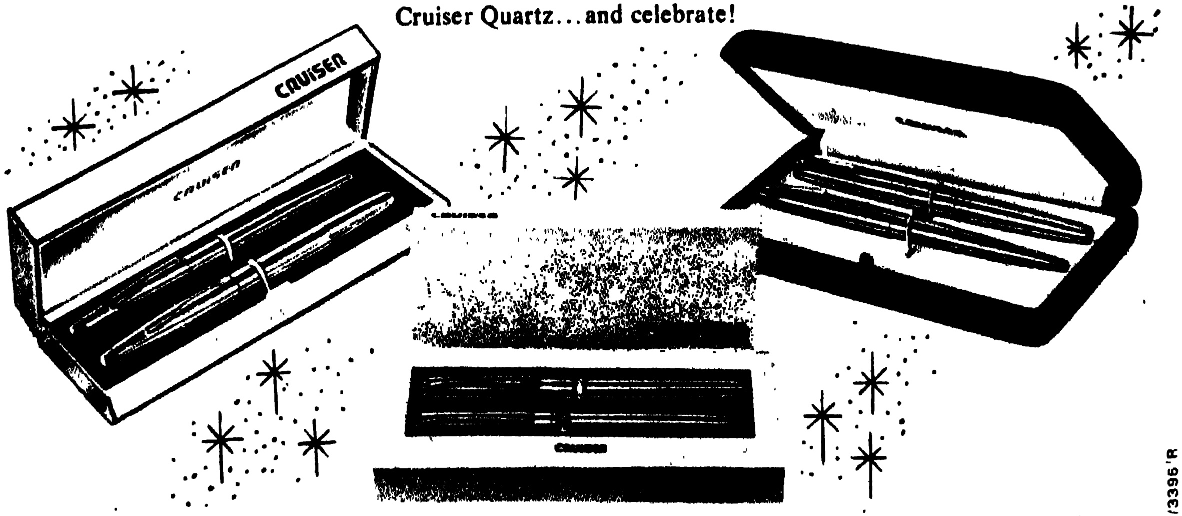

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TELL US...

... how fishes stand still in water?

FISHES exhibit a fascinating variety of movements, though normally the common one is that of swimming freely in the water. In order to fit well in their ecological niche and habitat, different fishes swim strongly or slowly, glide or jump, or even fly. Accordingly, their shapes also vary widely. But how do we account for the fish poised still in midwater? At one stage or another, many of us must have seen this sight in an aquarium, with the fish exhibiting only a slow, lazy motion of its anterior fins—the pectoral fins, apparently to offset the forward movement due to the water flowing backward out of the gill-covers. This ability of a bony fish to hover in water like a humming bird without active muscular action is due to the presence of an organ—the gas bladder, unique to fish.

To float, hover, or to 'stand' still in midwater, the fish must displace just the amount of seawater equal to its weight. In such a case, the buoyant force (equal to the weight of displaced seawater) just balances its weight allowing it to idle in a stationary position. But fish tissue is much heavier than seawater and will displace much less water. The bladder helps it to displace sufficient water, but it must have the right size. Calculation shows that the bladder volume should be about 4.6 per cent of the total body volume; in practice, too, we find the proportion to lie between four and five per cent.

The gas bladder (commonly called the swim or the air bladder) resembles a balloon-like sac and is filled with gases (a mixture of oxygen, carbon dioxide and nitrogen). It lies in the body cavity of the fish just below the kidney and above the stomach and intestine. It originated as a diverticulum or an appendage of the digestive tract. Primitive teleosts (ray-finned bony fishes, for example, herring) retain this connection, where the bladder is attached to the gullet (a condition called physostomous), while the more advanced teleosts (perches, etc) have done away with it (physoclistic). In other unrelated fish lines, the swim bladder has assumed important functions—like that of a lung, or at least as an extra breathing organ richly supplied with blood vessels. Not surprisingly, such fishes drown easily when denied access to the surface, even in well-oxygenated waters.

In rare instances of deep sea fishes even oil is present in the bladder, while bottom-living and deep sea forms have either drastically reduced or even have no swim-bladders. They have no use for it. The developmental pattern of the bladder follows that of lungs of land vertebrates and not of the digestive tract. Presumably, these structures have a common design in primitive fishes.

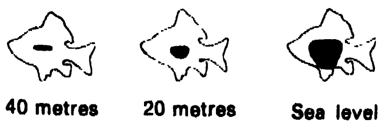

Fig 1. Expansion of swim-bladder

Where the bladders have assumed a role in deciding the depth of water at which the fishes have to live, their action is highly sophisticated in adjusting the amount of gases in the bladder. These gases are extracted from the blood by a gas gland, which covers a major portion of the inner surface of the swim-bladder. The gas gland gets its blood supply from the blood vessels of the *retia mirabilia*, branching into hundreds of subdivisions so that capillaries containing arterial and venous blood run parallel to each other and intermingle (SCIENCE TODAY, January 1980, page 34). Hence, transfer of dissolved gases from the blood to the swim-bladder is achieved. This increases the volume of the bladder and the fishes maintain buoyancy.

If too much gas were produced in the swim-bladder, the fish would float up, without being able to go down. When the bladder is attached to the gullet, the gas escapes through the mouth. In a healthy fish, excess gases are also removed from the swim-bladder by the action of a special part of the swim-bladder called the "oval". This is a thin-walled, highly permeable area of the swim-bladder richly equipped with blood capillaries. The oval is situated at the posterior ventral part of the swim-bladder and is surrounded by circular and longitudinal muscles. When the circular muscles contract, the oval is closed, stopping the removal of gases. Alternatively, when these muscles relax and the longitudinal muscles contract, the oval is exposed and the gases can be reabsorbed.

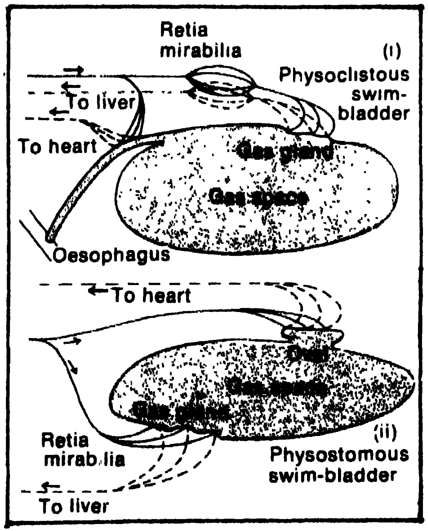

Fig 2. Diagrammatic representation of two types of gas-bladder (i) opening to the gullet and (ii) closed gas-bladder

When a physoclistic fish, where the swim-bladder is closed and has no external opening, is rapidly brought up to the sea surface, the oval cannot cope with the fast-decreasing pressure and the gases in the swim-bladder expand. (According to Boyle's law, gas expands as pressure decreases.) The swim-bladder ruptures killing the fish. If one visits a fish market, one witnesses many a fish with their swim-bladders sticking out of their mouths. Fig. 1 shows how a swim-bladder expands as a fish is brought up from a depth of 40 metres (at which it is under a pressure of five atmospheres) to the surface of the sea (a pressure of one atmosphere).

Increases in pressure, as the fish dives deeper and deeper into the waters, have no effect on the oxygen dissolved in the water and which is breathed by the fish. But man and other air-breathing animals are immediately faced with a serious problem, as soon as they enter or live in water. When the animal dives, the increase in pressure decreases the volume of the lungs. This forces the gases into the blood. Large quantities of nitrogen under pressure readily dissolve in tissues, and may lead to a toxic condition. Popularly termed as the raptures of the deep or nitrogen narcosis, the results can be fatal. Alternatively, while rising rapidly to the surface, the pressure decreases rapidly and nitrogen in tissues comes out in the form of bubbles. The result is again painful and often fatal.

This situation is not faced by air-breathing animals that live in the sea and dive to great depths. They have a unique reflex action; before diving they exhale rapidly thereby reducing the volume of air in the lungs. The rate of heart beat decreases and blood flow is decreased to most parts of the body, except the brain and the heart.

Many fishes which live on the sea floor, such as soles, gobies and blennies, do not have a swim-bladder. They have a body heavier than seawater and cannot hover, but have to exert muscular action for swimming at one level. The cartilaginous fishes, such as sharks and sting rays, also do not have a swim-bladder and cannot hover; but their enormous liver is rich in a hydrocarbon oil—squalene, which has a specific gravity of only 0.86, much lower than that of seawater. This serves to counterbalance the weight in excess of seawater in other tissues.

B. F. CHHAPGAR

Dr. Chhapgar is a scientific officer for aquatic radioactivity studies at the Bhabha Atomic Research Centre, Bombay.

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Intruder alarm

SEVERAL commercial models of burglar alarms are available. You can install them at various points in your house. If you live in a flat, you can have a joint alarm system with your neighbours and the flats immediately above and below yours. Switch it on when you go out, and if your house is burgled, your neighbours will be alerted.

If you have a flair for electronics you could build an alarm system for yourself. This two-way alarm system can spot the culprits inside and outside your home.

If you look at the circuit diagram of the intruder alarm you will know that the circuit is the simple modification of the "Undervoltage alarm for cars" (SCIENCE TODAY, September 1981, p. 73).

To understand the operation of the device, the circuit diagram can be divided into three parts. The right-hand part of the circuit is the step-down transformer with rectifier filter to provide about 15V DC for the operation of the device. The centre part is the audio oscillator using IC 555 in an astable mode of operation. The left part of the circuit is for sensing interruption of the light beam and "break wire". When light falls on any one of the LDRs uninterruptedly, the LDRs remain in conduction and keep the transistor BC 107 in saturation. The transistor, through the "break wire", keeps the reset terminal of the IC 555 virtually shorted to ground.

When the break wire is cut, the reset terminal of the IC no longer remains grounded and the IC 555 comes into astable operation. Similarly, when the "break wire" is continuous, but the light falling on one of the LDRs is interrupted, the increase in its resistance does not allow sufficient current to pass through the base of transistor BC 107. The collector emitter path, thus, is no more shorted, and the IC 555 starts astable operation.

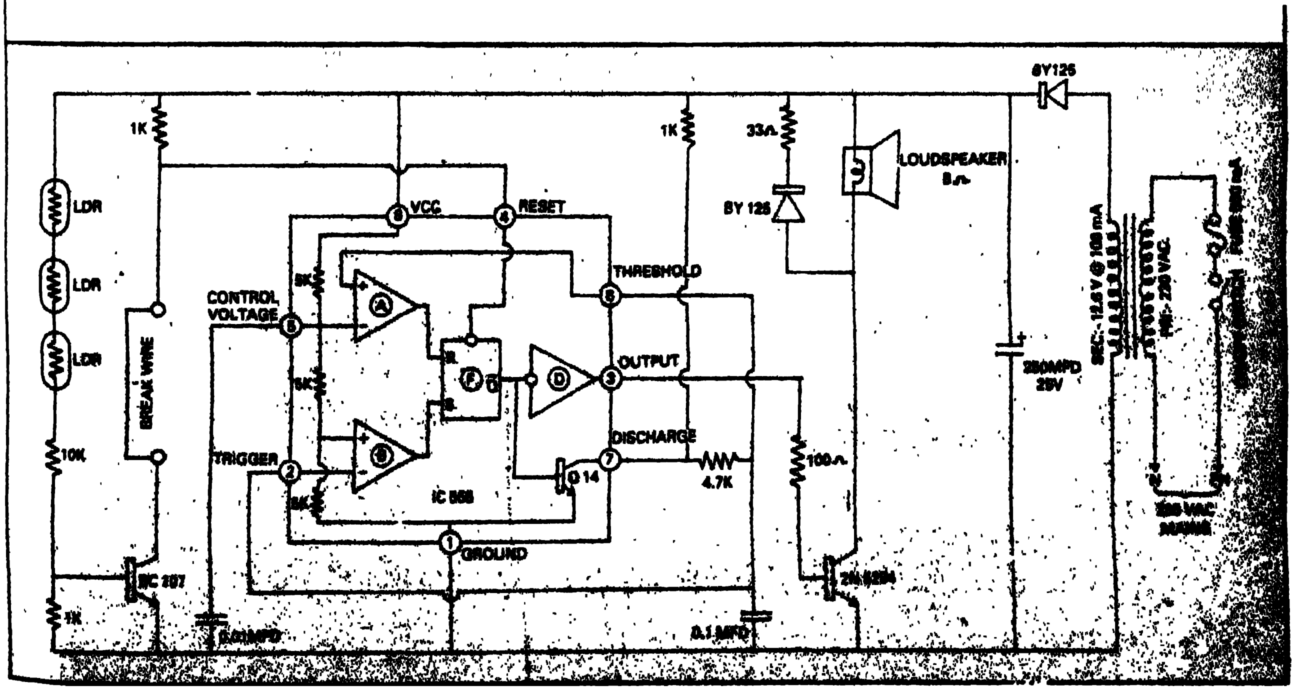
The IC 555 used as an astable, that is, free-running multivibrator, has its trigger terminal 2 connected directly to the threshold terminal 6. Thus, to start with, the 0.1 mfd timing capacitor has no charge over it. This triggers the lower comparator which, through the control flip-flop and inverting amplifier, drives the output high and simultaneously makes the discharging transistor Q14 non-conductive. This causes the capacitor to charge through the 1K and 4.7K resistors. When the capacitor charges to ⅔ Vcc, that is, the threshold level of the upper comparator, it resets the flip-flop, which in turn drives the output to its normal low state and brings the discharging transistor back to conduction. As the terminal 7 of the IC is now clamped to ground through the discharging transistor, the timing capacitor, instead of charging, starts discharging through the 4.7K resistor. The voltage across the timing capacitor falls. When the voltage falls to ⅓ Vcc level, the lower comparator gets triggered and once again changes the state of output and discharging transistors. This causes the capacitor to charge again. This completes one cycle and initiates the next.

The process continues, making the capacitor charge and discharge to ⅔ Vcc and ⅓ Vcc levels, respectespectively. The circuits go through about 1500 cycles of operation per second. The repetitive high- and low-going output provided by this stage drives the loudspeaker-driving transistor and the loudspeaker produces an audio alarm.

Installation of the intrusion alarm

a) *Break-wire part:* The break-wire should be a very thin, easily breakable wire of about 36 SWG or more. Between the two terminals, the wire should be electrically continuous. If enamelled copper wire is used, the end of the wire should be cleaned properly with a sharp blade so that the insulating layer over the wire is completely removed. This wire can be run outside the house, over fences, doors, windows, etc in such a way that the wire will break without the intruder noticing it.

b) *Photo-electric part:* You may use one, two or three LDRs. If more than one, they have to be connected in series. Ordinary mains-operated lamps can be used to illuminate the light-dependent-resistors (LDRs). The LDRs should be mounted inside the tube and the tube should be placed pointing towards the lamp. This type of arrangement can be repeated three or four times at various places inside the house. So when an intruder comes inside the house, he will interrupt the light falling on any one of the LDRs. While placing the LDRs, make sure that it is not illuminated by any light



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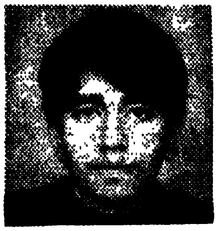
WEST ZONE **35 out of the first 50**  Jayanta Sen	**1. Jayanta Sen**	**Bombay**	**3rd**
	2. K. Padmanabhan	Pune	4th
	3. Dhaval B. Dalal	Ahmedabad	5th
	4. Nilkanth N. Phadnis	Sangli	6th
	5. Parimal N. Shah	Bombay	7th
	6. Girish B. Kulkarni	Bombay	9th
EAST ZONE **25 out of the first 50** Subrata Bhattacharjee	**1. Subrata Bhattacharjee**	**Narendrapur**	**2nd**
	2. Jyotirmoy Daw	Calcutta	6th
	3. Shekar Bapat	Visakhapatnam	7th
	4. Debasis Basu	Narendrapur	8th
	5. Sujoy Deb	Calcutta	9th
	6. Arnob Roy	Calcutta	10th
NORTH ZONE **(Delhi)** **30 out of the first 50** Praful Gundhi	**1. Praful Gundhi**	**New Delhi**	**1st**
	2. Raj Agrawal	Nainital	3rd
	3. Neel Madhav	Jaipur	4th
	4. Rahul Mittal	Muzaffarnagar	6th
	5. Vikrant V. Jituri	Faridabad	8th
	6. Rajesh Rathi	New Delhi	9th
NORTH ZONE **(Kanpur)** **16 out of the first 50** Pawan Agrawal	**1. Pawan Agrawal**	**Kanpur**	**1st**
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	6. Sanjay Srivastava	Gorakhpur	13th
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	6. Selvan Devasahayam	Madras	10th

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Radical

other than from the lamps mentioned above. A single lamp can also be used to provide illumination on more than one LDR. Suitable arrangements can be made to hide the lamps so that they are only "seen" by their respective LDRs. All the LDRs should be connected in series to the device.

Remember, an alarm system must be undetectable to be effective. Hence, you have to hide it or camouflage it.

You will need:

Semiconductors:

Integrated circuit IC 555—1 No.
Transistors: BC 107—1 No.; 2N5293 to 2N5296 any one, or any other silicon NPN medium—power transistor 1 —No.
LDR—up to 3 Nos.
Diode rectifier BY—125—2 Nos.

Capacitors: 250 mfd—25V electrolytic—1 No. Ceramic or polyester: 0.01 mfd—1 No.; 0.1 mfd—No.
Resistors (all ½ watt type): 10K—1 No.; 4.7K—1 No.; 1K—3 Nos.; 100 ohms—1 No.; 33 ohms—1 No.

Loudspeaker: 8 ohms 1W—1 No.
Transformer: Pri: 230 V AC. Sec: 12.6 V at 100 mA—1 No.

Approximate cost of the above components, using only one LDR, is Rs. 100 in Bombay.

Misc: Fuse 500 mA with holder, wires, screws, suitable enclosure, IC experimenter's veroboard, enamelled copper wire 36 SWG 100 gm, solder, etc.

ANIL V. BORKAR

BRAIN TEASERS

Daughter's age

I ASKED Mrs. Sulekha, "What is your daughter's age?" She replied, "The digits in her age are the reverse of the digits in my age, but after five years she will be half of my age." Can you find out her daughter's age (in whole numbers)?

SHANAZ BATHUL

(Solution next month)

Solution to last month's Brain Teaser

Square

Let a and b be the required digits.
Now $a^2 + b^2 - ab$ = a square

Let this square be $(a-mb)^2$,
where m is a whole number larger than 1.

$$a^2 + b^2 - ab = a^2 - 2abm + m^2b^2$$
$$b-a = bm^2 - 2am$$
$$b = \frac{a(2m-1)}{m^2-1}$$

When $m = 2$, the digits are equal.
When $m = 3$, $a = 8$ and $b = 5$.
When $m > 3$, a and/or b exceeds 9.
Hence, the required digits are 8 and 5.

"Add a square"

Mr. B. A. Naik, Mr. S. P. Pathak and Mr. N. N. Nigam have sent an alternative solution to the Brain Teaser "Add a square" (June 1981).

$(b+a)(b-1) = 1691 \times 1$.

$\therefore b = 846$ and $a = 845$

$1691 + 845^2 = 846^2$

Hence, the squares are 714, 025 and 715, 716.
This, too, is a correct solution—*Ed.*

SCIENCE ACADEMY MEDALS

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Instituted by the Indian National Science Academy in 1974 these medals are awarded annually in recognition of the outstanding work of scientists below the age of 32 (as reckoned on 31st December preceding the year of award). Only those born on or after January 1, 1950 are eligible for consideration in 1982.

With the medal there is a cash prize of Rs. 5,000/-. In addition, the recipient is considered for a research grant by the Academy.

Nominations for the awards for 1982 may be made by Fellows of the Academy, as also by established scientific societies of an all India character, University faculties and departments, or research institutions.

The last date for the receipt of nominations in the Academy is December 1, 1981.

Nominations received in previous year(s) will not stand carried forward.

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MEETINGS CALENDAR

December

30 Nov-11 Dec: Radiation emergency preparedness (health physics and medical aspects) for the region of Asia and the Pacific, IAEA seminar, RRC, Kalpakkam, Madras (Department of Atomic Energy)

1-4: Incidence of infectious and chronic diseases - geographical perspectives, int. symposium, Madras (Department of Geography, University of Madras, Madras)

3-5: Plant breeding and genetics, 4th annual symposium on plantation crops (PLACROSYM-IV), Central Food Technology Research Institute, Mysore (General Chairman, Placrosym IV, Director of Research, Central Coffee Research Institute, Coffee Research Station 577117, Chikmagalur District, Karnataka)

3-5: Advances in science and technology of mineral beneficiation in India, symposium, AMD Complex, Begumpet, Hyderabad (Department of Atomic Energy)

9-11: Flood disasters, int. conference, INSA, New Delhi (The Executive Secretary, Indian National Science Academy, 1, Zafar Marg, New Delhi)

9-18: Application of computer techniques for development, Kanpur (B. Raj Bhandari, UNESCO House, 17, Jor Bagh, New Delhi-110 003)

10-11: Soldering in electronic component and instrument industries, solder seminar II, Sea Rock Hotel, Bombay (Solder Seminar Secretariat, Indian Lead Zinc Information Centre, B-6/7, Shopping Centre, Safdarjung Enclave, New Delhi-110 029)

11: Indian Hospital Association, 21st annual convention, New Delhi (P. N. Ghei, Indian Hospital Association, Nirman Bhavan, New Delhi-110 011)

11-13: Water resources conservation, pollution and abatement, int. symposium, Roorkee University (Prof. R. J. Garde, Prof. and Head of Civil Engineering Dept., Roorkee University, Roorkee-247 672)

12-16: Societies in transition: alternative for the future, int. seminar, Cuttack, Orissa (Prof. Chitta Ranjan Das, Institute of Oriental and Orissan Studies, "The Universe" Maitree Sarani, Cuttack-753 001, Orissa)

14-19: Condensed chromatin and human X-chromosomes, symposium, Indian Institute of Science, Bangalore (Prof. H. Sharat Chandra, Microbiology and Cell Biology Laboratory, Indian Institute of Science, Bangalore-560 012)

14-26: Carcinogenicity, mutagenicity and teratogenicity, workshop-cum-course, Bombay (Dr. M. G. Deo, Indian Association for Cancer Research, Director, Cancer Research Institute, Parel, Bombay)

16-20: Neurological Society of India, annual conference, Visakhapatnam, A.P. (Dr. S. N. Bhagwati, Secretary, Neurological Society of India, Medical Research Centre, Bombay Hospital, Bombay-400 020)

16-20: Environmental education, int. conference, IARI, New Delhi-110012 (Dr. M. S. Swaminathan, member, Planning Commission, Yojana Bhavan, Parliament St., New Delhi-110 001)

17-19: Systems theory and its applications, int. conf., Punjab Agricultural University, Ludhiana, Punjab, India (Prof. R. K. Varshney, Organising Secretary, International Conference on Systems Theory and Applications, Electrical Engineering Department, PAU, Ludhiana-141 004.

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IF...

... the DNA repair mechanisms malfunction

DEOXYRIBONUCLEIC acid (DNA) is the primary, genetic material of all cellular organisms. The two main functions of DNA are to replicate itself and to control cellular functions. DNA is organised into chromosomes, as a giant molecule, the replication of which must be accomplished with high fidelity. Errors during replication do occur, however, and these may manifest as mutations. DNA is also subject to insults from external agents which not only affect its integrity, jeopardising the survival of the cell but also may result in increased mutation, cancer and even accelerated ageing. DNA repair mechanism has evolved not only to redress the damage induced, but also to modify the mutation frequency.

The double-helical chain of DNA has four different building blocks (nucleotides) which are held together by complementary base-pairing. During DNA replication, the two chains separate and each chain provides a template for the complementary strand, the sequence of nucleotides of one strand fixing the sequence of the opposite complementary chain. DNA is laterally differentiated into genes which are segments of specific sequences of nucleotides. Genes are expressed by first specifying another nucleic acid (an RNA) and the information is then 'translated' into proteins.

Ordinarily there is only one copy of a gene in a haploid organism and two copies in a diploid organism. This relative uniqueness of the genetic material is reproduced with high-fidelity. If replication errors are not corrected, heritable changes in the genes—mutations—may occur. The mutational variability is the raw material for natural selection which thus could improve the adaptation of a species. On the other hand, most of the mutations are detrimental and an increase in the insults caused by environmental agents could not only increase the mutational burden but also affect the survival of the cell itself. And, that's where the DNA repair mechanisms come into play.

A number of DNA repair mechanisms coping with diverse types of damage have been discovered. An early discovery was of the so-called excision-repair mechanism of ultra-violet radiation (UV)-induced damage in the colon bacterium *E. coli*. The main damage induced in DNA by UV radiation results in a pyrimidine dimer—a fusion of two adjacent pyrimidines (thymine and cytosine). If not corrected, the DNA replication stops at the dimers. Strains deficient in a gene concerned with DNA repairs survive poorly. This excision repair is error-free, which is to say that no mutations are produced after repair. But there are other DNA repair mechanisms which are error-prone. Thus if a cell is deficient in excision-repair, some of the repair can be carried out by post-replication repair which, however, is error-prone yielding a high frequency of mutations.

A recently-discovered adaptive mechanism is even more interesting. If bacteria initially receive a low dose of a mutagen and a carcinogen, say, N-methyl-N-nitrosoguanidine (MNNG) and are subsequently exposed to a high (challenge) dose, they usually become resistant and survive without undergoing any mutations. This observation finds a parallel in an animal system in which rat livers pretreated with low levels of carcinogen, dimethylnitrosamine, show an enhanced level of repair capacity. R. B. Setlow of Brookhaven National Laboratory, once jokingly said in a seminar on adaptive mechanisms, "who knows, exposure to a little bit of mutagen/carcinogen may be good for you".

If the DNA repair capacities have such profound effects on cell survival and mutagenesis, then what about their implications for carcinogenesis? One of the theories implicates somatic mutations in carcinogenesis. In support of this hypothesis, a majority of carcinogens have found to be mutagens in bacteria. Therefore, deficient DNA repair capacities enhancing mutation frequencies would have strong implications for carcinogenesis too.

In humans also a genetic condition imparting deficiency of DNA repair has disastrous consequences for the patient. Thus, xeroderma pigmentosum (XP) patients with a DNA repair disorder develop multiple, malignant changes in the skin during childhood and early adult life, unless exposure to sun (UV light) is avoided. Mutation frequency is also affected. Apparently, the increased mutagenesis is due to the slow removal of carcinogen-altered bases and, therefore, a higher probability of inducing mutation at the replication point.

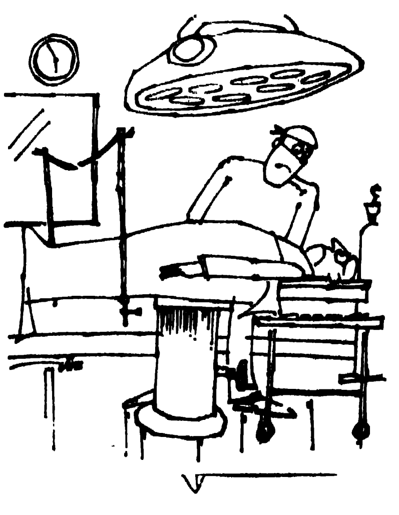
There are other genetic disorders in man (for example, Fanconi's anemia and Bloom's syndrome) where deficient repair systems and consequently increased carcinogenicity are implicated. Even for Ataxia-telengiectasia (AT) condition, it was considered that there is a repair-defect for X-ray induced damage. Surprisingly, AT cells exposed to X-radiation do not show the normal delayed response of DNA synthesis. From this observation it is inferred that the defect is in the response to DNA damage.

Although, the problem of ageing is perhaps even more intractable than that of cancer, there is nevertheless some circumstantial connection between the cellular repair capacity and ageing. A rare genetic disorder, progeria, is associated with premature ageing and early death. Here, cells were found defective in the repair of gamma-ray damage. A gross correlation has been provided between the life-span of a species and its repair capacities. Seven mammalian species were studied and the inference was that unrepaired alterations in the structure of DNA could lead to a shorter life-span.

Discovery of the DNA repair systems was made in the course of basic radiobiological studies, and soon the connection between some of the repair systems and mutagenesis became apparent. Thus, DNA repair is not only crucial for the survival of the cell but also provides optimal mutation rates for the organism to adapt. Speculatively, the breakdown or deficiency of repair systems could also lead to an increase in errors which may eventually result in increased cancers or even accelerated ageing. Our deeper understanding of DNA repair systems could provide the necessary framework for a systematic attack on the problems of genetic burden, cancer and even ageing.

N. K. NOTANI

Dr. Notani is with the Biology and Agriculture Division, BARC, Bombay.



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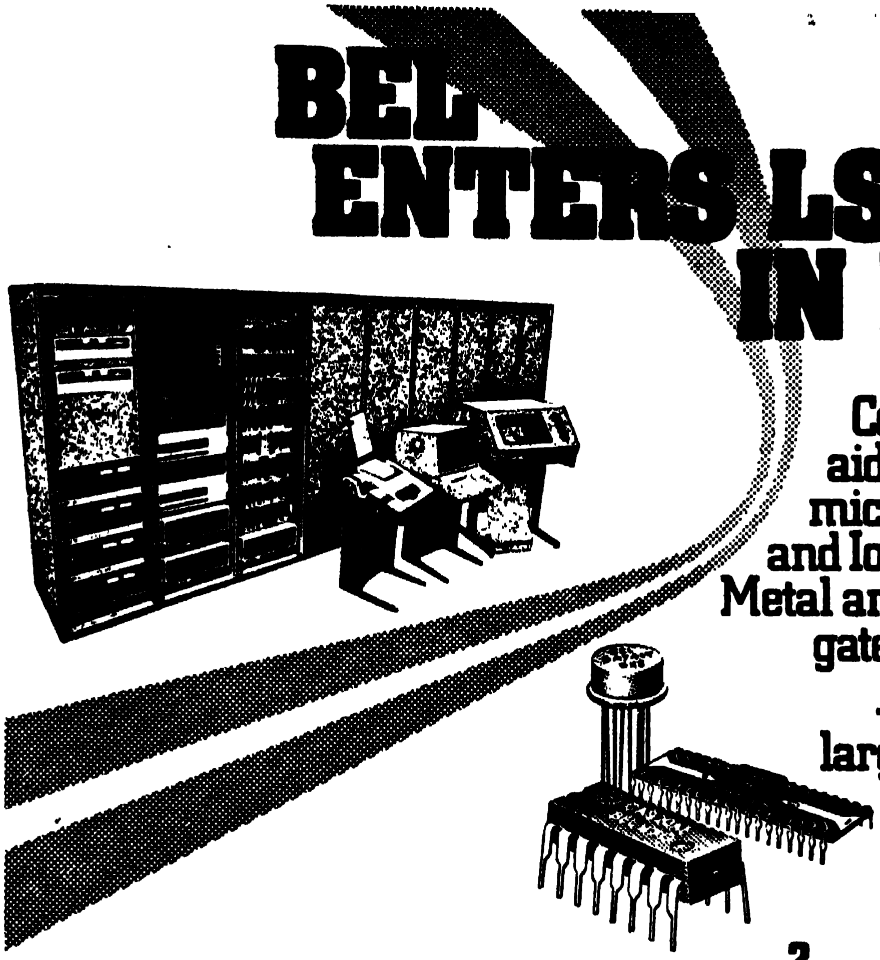

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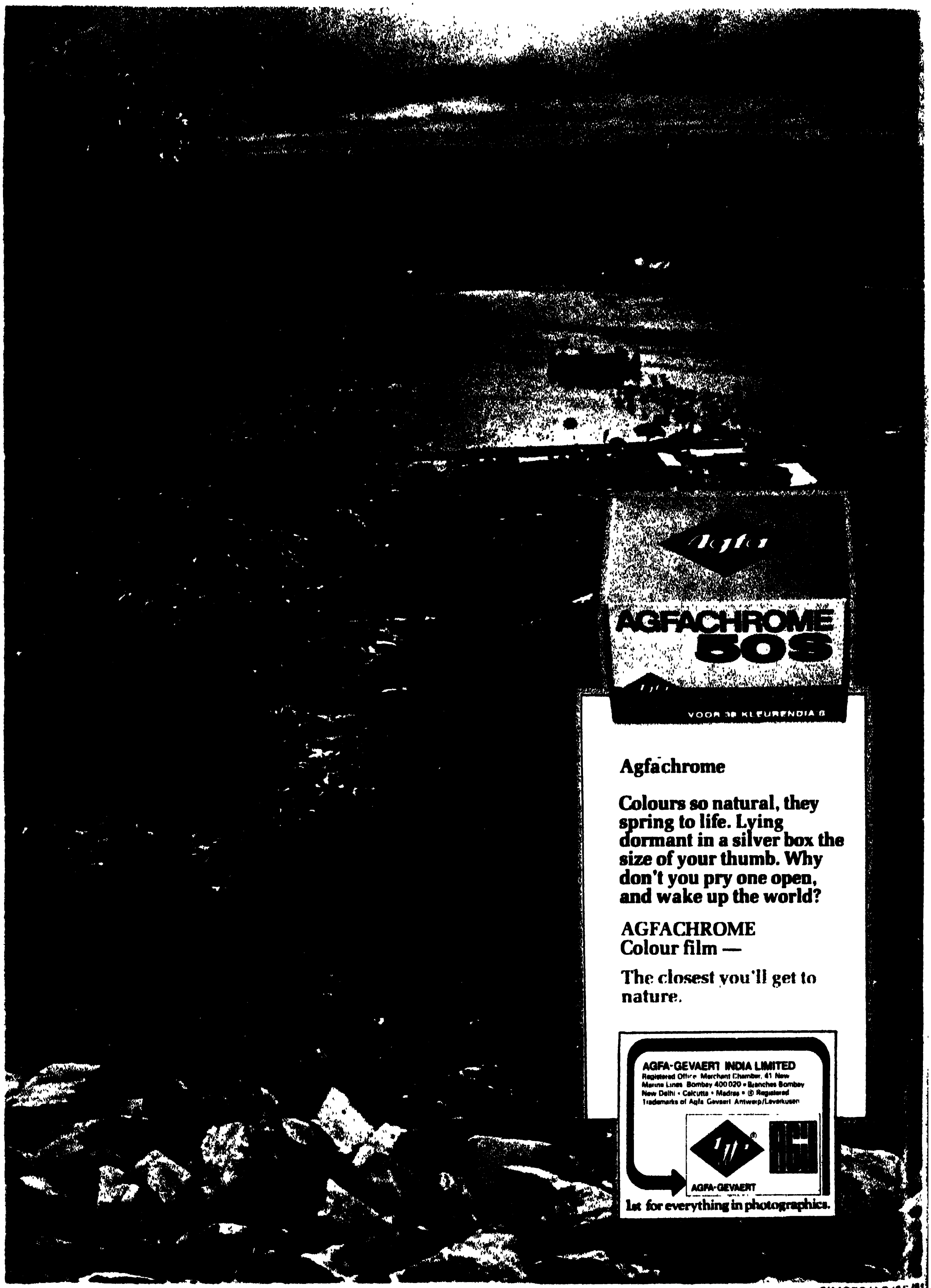

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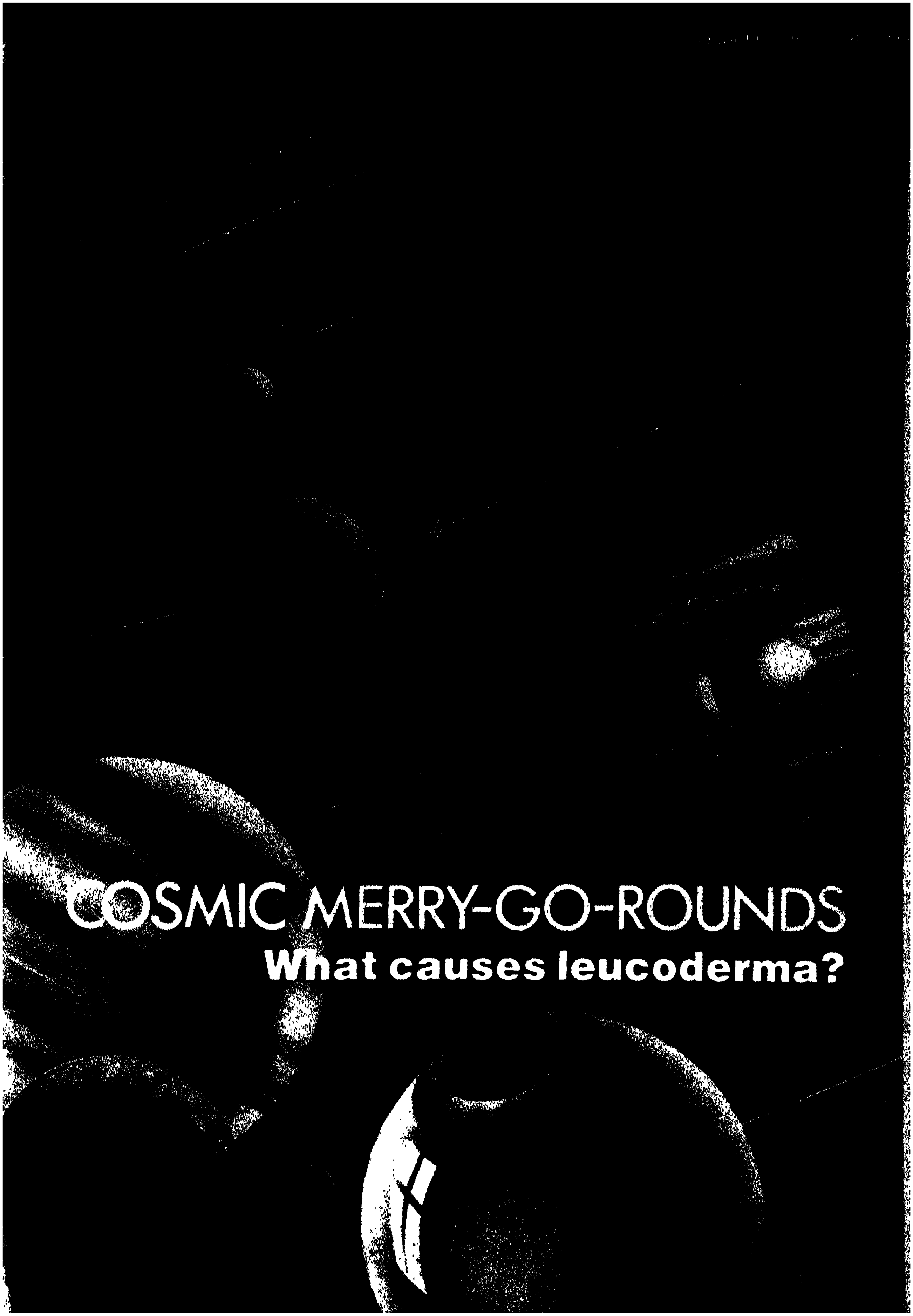

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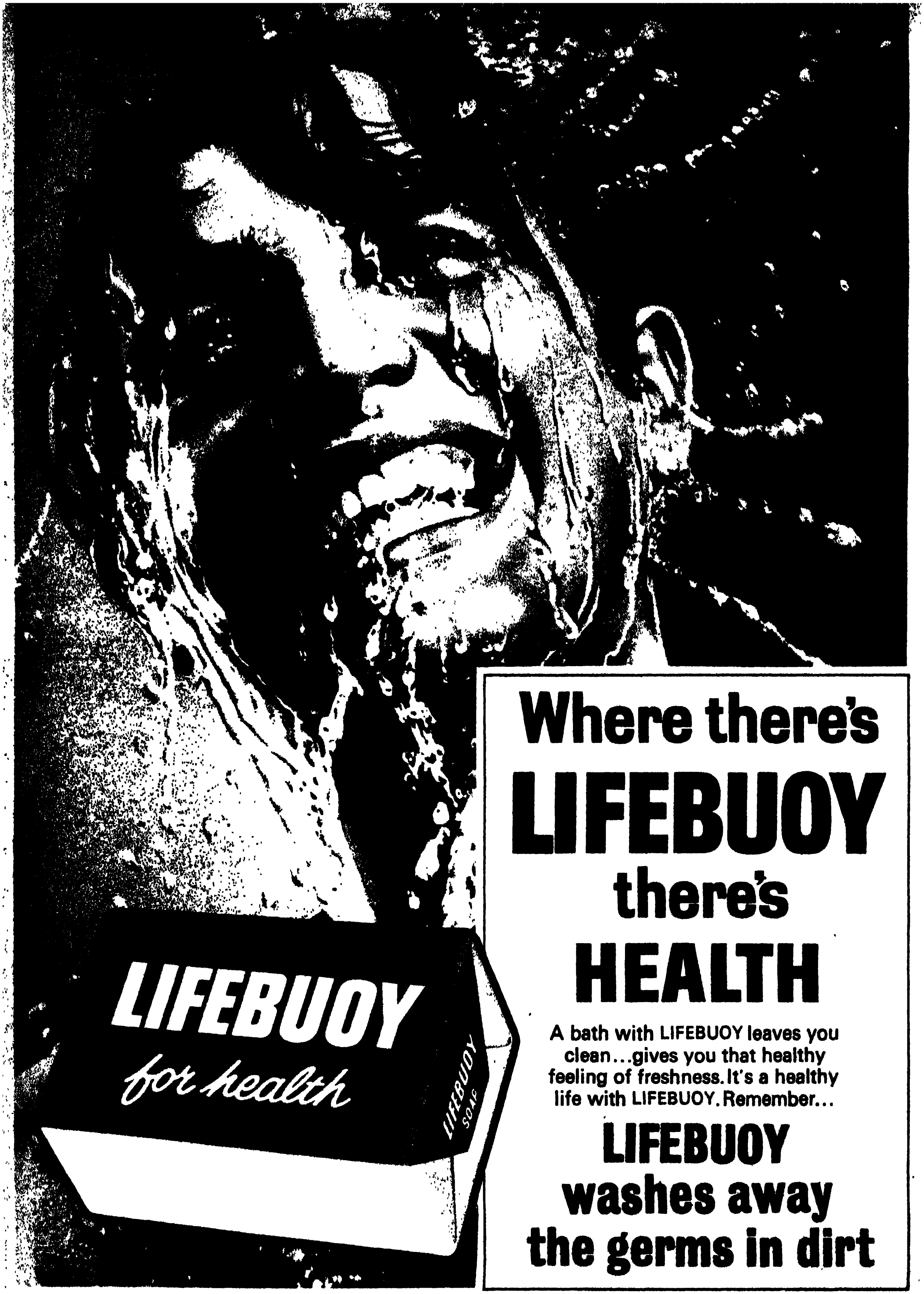

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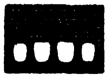

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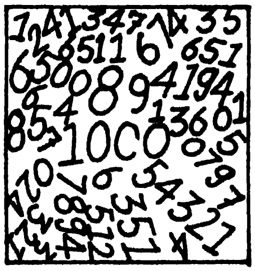

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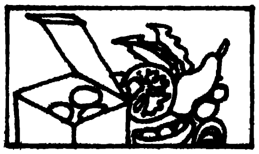

Micronutrients you can't do without
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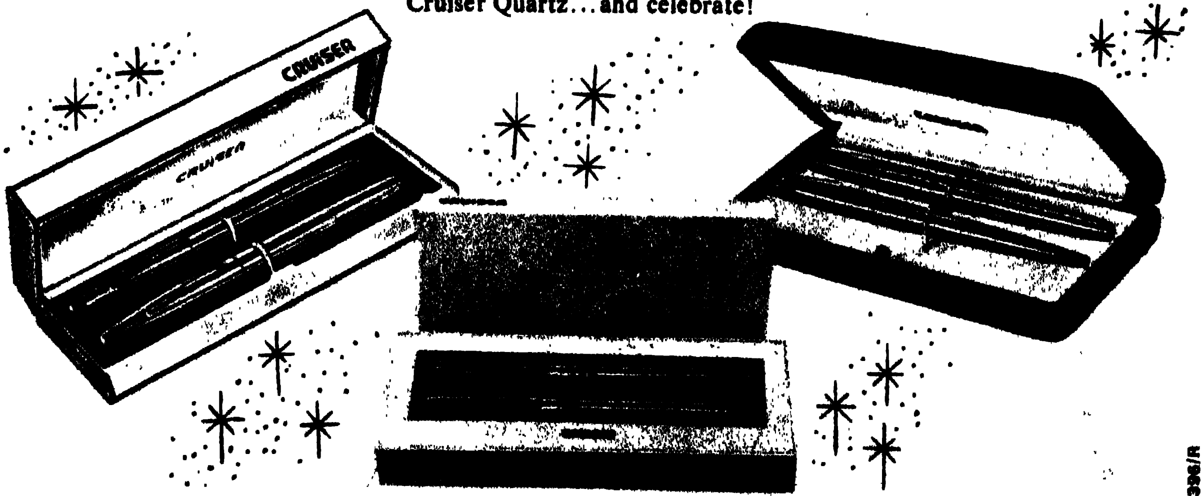

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LETTERS

UNIQUE GOATS OF BARREN ISLAND

THE high degree of salt tolerance of the desert goats ("A New Look at the Goat", Science Shapes Life, April 1981) reminds me of a flock of 400 to 500 feral Indian goats that I had seen during 1965-67 in the course of my naval duties in the Barren Island, also called the Goat Island, about 145 km north-east of Port Blair. There was no source of sweet water anywhere on this tiny island, and the goats merrily thrived on sea water (average salt concentration 34g/kg), without any sign of discomfiture. Legend has it that the goats we saw there were the descendants of a few survivors from a shipwreck that managed to swim ashore in the distant past. No one apparently knows the details, but lack of predators including man and, more important, the goat's acceptance of sea water, must have accounted for their sizeable population on the island. In fact, these animals were so much accustomed to drinking saline water that we found it hard to induce a few of them to take to sweet water.

I wonder if there are many such instances of livestock breeds which live on sea water. If not, the Barren Island goats must be truly remarkable and may call for serious scientific investigations.

COMDR. I. S. BHATIA
(Retd.)
Sagaran P. O.
Jodhpur (Rajasthan)

ARE THE SCRIPTURES RELEVANT?

A MAN must be brave enough to accept that beliefs are not eternal. Sticking to ancient scriptures without paying head to their contemporary relevance amounts to fanaticism. I totally endorse the view of P. N. Haksar (Letters, September 1981) that absurdities of the scriptures must be defied. Bertrand Russell, in *An Outline of Intellectual Rubbish*, satirises the irrational attitude of fanatics: "In practice, people choose the book considered sacred by the community in which they are born, and out of that book they choose the parts they like, ignoring the others. At one time, the most influential text on the *Bible* was: 'Thou shalt not suffer a witch to live.' Nowadays, people pass over the text, in silence if possible, if not, with an apology. And so, even when we have a sacred book, we still choose as truth whatever suits our own prejudices."

ARUN GAUR
English Department
Punjab University
Chandigarh

TRUE Islam would support what P. N. Haksar says. The history of Islam shows that the self-appointed rulers after the death of Ali discouraged pursuit of the mind! The children of Fatima, Mohammad's daughter, favoured learning with remarkable liberalism. They were not devoted to the past, as with Mohammad's precepts, to light the path. They devoted themselves to the development of humanity, and so to the cultivation of science and learning in all its branches.

SYED AHMAD ALI
Guzri,
Patna 800 008

MR. HAKSAR has used the word "philosophy" in his letter. I am reminded of an article "Thinking About The Brain" by F. H. C. Crick in the September 1979 *Scientific American*, where he writes: "...Perhaps a more dramatic illustration is the presence of a blind spot in each eye. Not everyone realites he has a blind spot, although it is easy to demonstrate. What is remarkable is that we do not see a hole in our visual field. The reason is partly that we have no means of detecting the edges of the hole and partly that our brain fills in the hole with visual information borrowed from the immediate neighbourhood. Our capacity for deceiving ourselves about the operation of our brain is almost limitless, mainly because what we can report is only a minute fraction of what goes on in our head. This is why much of philosophy has been barren for more than 2,000 years and is likely to remain so until philosophers learn to understand the language of information processing."

K. C. GEORGE
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Palai 686 575
Kerala

ANATOMY OF NERVE FIBRES

IN "Multiple Sclerosis: Looking for the Cause" (Science Shapes Life, August 1981), there is some confusion about the anatomy of nerve fibres and myelin sheath. A single nerve fibre is really an axon (the extended process of a nerve cell through which nerve impulse travels down from the cell body) surrounded by layers of myelin. The sentence, "Each segment of these fibres (nerve fibres) is completely embedded in lamellar myelin" is not quite correct because it is the myelin and not the nerve fibre that is segmented. Further, the nerve fibre is not "completely embedded in myelin", but at repeated intervals along a fibre there are regions where it is not covered with myelin. This gives the appearance of nodes to the myelinated nerve fibres and are referred to as the nodes of Ranvier. The presence of these nodes facilitates speedy propagation of impulses which is otherwise much slower as in unmyelinated fibres. Although it is well known that oligodendrocytes are concerned with the production of myelin, it is not clear if each segment is produced by a single oligodendrocyte cell as implied in your columns.

In multiple sclerosis-affected organs of the central nervous system, no virus has been detected; nevertheless, the cerebrospinal fluid has been found to contain antibodies against common infecting viruses like the measles virus. The clinical signs in multiple sclerosis are typical and it is characterised by remissions and relapses; its pathology is also well understood. However, the cause of the disease continues to elude the scientists and, in the absence of a known cause, a rational therapy is not available as a permanent cure.

MANJARI MUKHERJEE

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PROF. T. R. GOVINDACHARI AWARD

APPLICATIONS or nominations are invited for the Prof. T. R. Govindachari 60th Birthday Commemoration Award. Bio-data (4 copies), inclusive of a five-page summary of original research accomplishments, and a list and set of reprints of publications must reach us before 31 January 1981. The award, which is to be made to an Indian organic chemist working in India with a minimum of 15 years of teaching-cum-research experience, carries Rs. 5,000 in cash. Further details can be had by sending a 35p self-addressed envelope.

THE REGISTRAR
University of Madras
Madras 600 005

MEDICAL ENTRANCE

OUR TOPPERS-1981

Atul Bedi

1st in C.M.C., Vellore,
Selected in A.I.I.M.S., Delhi, JIPMER, Pondicherry, CMC, Ludhiana, Medical College, Calcutta, I.M.S., Banaras. Medical Entrance, Delhi A.F.M.C., Pune.

Preeti Aggarwal

1st in P.M.T. Panjab
2nd in Pre-Medical Panjab,
12th in Medical Entrance, Delhi (4th among girls).
Selected in CMC Ludhiana.

Sandeep Khurana

1st in Pre-Medical Panjab, 2nd in C.M.C., Ludhiana
4th in P.M.T. Panjab,
11th in Medical Entrance Delhi, Also Selected in A.I.I.M.S., Delhi.

Anita Deswal

1st in B.J. Medical College, Pune,
3rd in A.F.M.C.,
7th in Medical Entrance, Delhi
14th in JIPMER Pondicherry, Also selected in A.I.I.M.S., Delhi, M.G.I.M.S., Wardha, J.E.E. Bangalore, M.P. Shah Medical College Jamnagar, I.M.S., Banaras.

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- M.B.A. ENTRANCE

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Rajneesh Dube

1st in A.F.M.C. Pune, (Poona)
7th in I.M.S., BHU, Varanasi.

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Threshers are not for maiming

EVERY year many farm workers are rushed to city hospitals during the wheat threshing season (mid-March to mid-June) in the North, either with chopped or severely injured arms or hands. In a large number of cases, the patient is saved only by amputating the arm, crippling him for life. And the number of thresher victims, already very large, is increasing every year.

The Central Ministry of Agriculture, in a booklet entitled "Avoid Thresher Accidents", estimates an annual thresher casualty of over 1,000 persons ("annual" in this case means only during the three months when wheat is threshed). Let us see the statistics from hospitals in Delhi city alone: half way through the 1980 season—up to 7 May from the middle of March—98 victims (including 40 who had to undergo amputation) were admitted to Safdarjung Hospital and 58 (including 15 amputated) to Lok Nayak Jaya Prakash Narayan (JP) Hospital. By contrast, the figures for the entire 1979 season were 140 at Safdarjung and 58 at JP Hospital. In a single month in April 1981, 25 cases were recorded at Safdarjung, 29 at JP Hospital and 68 (also including victims of the *Kohlu*, the sugarcane crusher, and the printing press) at Hindu Rao Hospital. All these victims come from the rural areas of Sonepat, Panipat, Meerut, Ghaziabad, Bulandshahr, Gurgaon, and Delhi regions, all within a radius of 100 km of Delhi.

Wheat threshers are widely used, mainly in the wheat-growing northern states of Punjab, Haryana, Uttar Pradesh, Rajasthan, Bihar and the Union Territory of Delhi. According to rough estimates, there are over two lakh and thirty thousand threshers in Punjab alone. The total number of wheat threshers in the country at present is estimated at about ten lakhs.

Mechanical and power threshers were introduced as a direct consequence of the "Green Revolution" and the high-yielding varieties of wheat. Faced with phenomenal yields, the big farmers were unable to thresh their crop before the onset of the monsoon by conventional means (the *phalla* method using animal power). The big landlords needed faster means of getting on with the job, and a number of small-scale industries, which were then emerging in Haryana, Punjab and the Union Territory of Delhi, came forward to provide the means: mechanical and power threshers. It is surprising that even big business firms involved in the production and marketing of tractors and harvesters did not enter the market for the threshers. Currently, in Punjab alone, there are over 2000 small-scale manufacturers of threshers. Like in the early days of the Industrial Revolution in Europe, the introduction of threshers has led to several problems in rural India; not only did it literally draw blood, but also exposed child labour to the hazardous working conditions on the threshers.

Dangerously unsafe

Of the many types of threshers available in the market, the drummy, hammer-mill, syndicator (chopping), spike-tooth cylinder, and rasp-bar cylinder types are the most prominent. But most of the threshers in use are the chopping and the drummy types.

In the chopping type thresher, the thresher unit consists of a corrugated fly-wheel with serrated chopping knives and a closed cylinder casing and concave. In the drummy type, hammers or beaters with a closed cylinder casing and concave are provided for threshing. It usually consists also of a centrifugal blower for partial separation and cleaning of the grains. Different types of threshers have different kinds of feeding systems: the chute, hopper, conveyor or feeder roller. For drummy and hammer-mill type of threshers, the Indian Standards Institution has recommended the chute feeding system. The feed roller with the chute or conveyor is recommended for the chopping-type threshers.

Of all the feeding systems, the chute is the simplest in design and the most economical. It consists of a simple mild steel trough through which the crop is fed manually. Other feeding systems have somewhat complicated designs and need skill in handling. Besides, they are costly.

Both the chopping and drummy-type threshers are accident-prone, the only difference being the nature of injury inflicted (Table 1). In the drummy type, the arm is severely crushed or mangled, with some possibility, in a few cases, of hand surgery to restore partially the functional value of the arm. The chopping type, however, cuts the fingers or part of the forearm right through, causing an irreparable loss of the limb.

In the opinion of Prof. G. C. Das, one of India's leading hand surgeons, who is deeply involved in the problem of thresher victims, the functional value of the hands could be restored to some extent in only 25 per cent of the victims of the drummy-type threshers. The question of restoration of the functional value of the hands does not even arise in the case of the victims of the chopping-type threshers, at least 75 per cent of whom have to undergo amputation. Medical rehabilitation of upper limb amputees is almost impossible in India. For one thing, a reasonably functioning artificial hand is still under development; for another, it is enormously expensive and far beyond the reach of a farm worker.

How do accidents occur?

Most of the thresher accident victims are poor and illiterate hired local or migrant workers. The most disconcerting feature of these accidents is the substantial number (about 22 per cent in a 1980 survey) of children between the ages 10 and 18 years that are injured. The owners or employers are rarely the victims. The numbers given here refer only to the reported cases, that is, those who seek medical aid in city hospitals and for which records are maintained. The actual number is much larger. It is estimated that the rate of thresher accidents will top the list of accident rates in the industrial sector.

Table 1. Type of threshers involved in accidents

Type of thresher	Contribution to accidents (per cent)	
	1976*	1980*
Drummy	45.16	29.03
Syndicator (chopping)	37.42	56.46
Hammer-mill	14.19	9.68
Spike-tooth cylinder	1.29	1.61
Beaters on reels	1.94	3.22

*Surveys conducted by PAU, Ludhiana; "Thresher accidents in the Punjab during the wheat threshing season of 1980" by S.R. Verma and B.S. Bhatia, PAU, Ludhiana, January, 1981.

There are mainly two reasons for such a high rate of accidents. First, most of the threshers have practically no safety devices to prevent accidents. Even in cases where the manufacturers provide some sort of safety devices in the threshers, these are removed to speed up the operation. This needs some explanation. Threshing usually takes place in the open fields, and the farmers are possibly worried about theft, rains, fire, duststorm, etc and would, therefore, like to finish the job as quickly as possible. When speed is given precedence, safety loses its importance, and the safety devices are removed. Second, and more important, the employers do not provide safe working conditions to the farm workers working on threshers. For example, lighting arrangement is poor at night when a slight human error may result in accidents, even with safety devices. One might well ask, why work at night. But, if the farmer does not get electricity during the day, he necessarily puts the labourers to work during the night when the power is on. Case histories of many accidents have revealed that most of the accidents occurred after four in the evening and when the victims were tired, sleepy, or hungry due to overwork. The Punjab Agricultural University (PAU), Ludhiana, concluded from two surveys in 1976 and 1980 that most of the accidents resulted from such human errors, while the remaining were caused by machine, crop and situational factors.

The large number of thresher accidents raises many questions. Is the government aware of the problem? If so, what is it doing to prevent accidents by way of improving the design and/or providing safety devices? Are scientists and technologists looking seriously into the problem? What happens to the thresher victims? Are they given proper medical treatment? What is being done to rehabilitate accident victims who lose the functional value of their arms or hands? In other words, the thresher problem raises different aspects of the use of technology in the agricultural sector. The thresher problem is thus as much a legal and social problem as it is a technical one.

Governmental efforts mainly on paper!

Let us examine the different steps taken by the Central Government. As early as August 1976, the Ministry of Agriculture wrote to Directors of Agriculture in various states, requesting them to ask the manufacturers "to provide a safety device in the threshers" and to organise "suitable training camps during the threshing season to educate the labour in the proper handling of the machines". On 25 July, 1978, the then Minister of Agriculture, Mr. Surjit Singh Barnala, wrote to the Chief Ministers of Punjab, Haryana, Bihar, Uttar Pradesh, Madhya Pradesh, Rajasthan and the Lt. Governor of Delhi, elaborating several measures to be taken. These included: (i) disallowing the manufacture of threshers without safety devices, (ii) enactment of necessary laws, (iii) payment of reasonable compensation to the victims by any employer using threshers without safety devices, and (iv) making available, free of charge, Central Government testing facilities to those trying to develop effective safety devices.

An interministerial committee then met in June 1979, almost a full year later, to consider the possibility of invoking existing laws to bring to book those responsible for thresher accidents. The Industries (Development and Regulation) Act of 1951, entry 10, and the Factories Act of 1948 could not be applied because of technical reasons. The Workmen's Compensation Act also was of little use for the thresher victims because almost all of them are casual labourers who are not covered by the Act. The committee, therefore, recommended making a fresh Act to cover thresher accidents, compensation, etc.

On 27 August, 1979, the Department of Science and Technology (DST) appointed an expert committee headed by Prof. A. C. Pandya of the Central Institute of Agricultural Engineering, Bhopal, to go into the existing designs of safety devices and to suggest minimum preventive measures for threshing machines. This committee met on 17 September, 1979, and, among other things, recommended the compulsory registration of all threshers in the country indicating the manufacture, type, date sold, and the buyer and his address. The committee said the dealer/manufacturer should also ensure that third-party insurance is taken by the customer. An interministerial committee under the chairmanship of Dr. M.G.K. Menon, Secretary, DST, met on 22 October, 1979. Accepting the recommendations of the expert committee (headed by Prof. Pandya), this committee suggested that "the Farm Machinery Industrial Extension Service Act and the Farm Machinery Education Act should be finalised and strengthened". As many of the victims happen to be children, the committee felt that the National Council for Educational Research and Training (NCERT) should be persuaded to initiate programmes on the use of threshers and its hazards. Another recommendation to the Ministry of Health and the Directorate-General of Health Services (DGHS) suggests that they should write to state governments to collect data on thresher accidents. (Incidentally, in spite of the fact that several thousands have suffered in the last decade, no reliable data are available on the number of victims, nature of injuries, number of threshers, etc, but government departments which should collectively be held responsible for the collection of data are worried about who should write to whom!)

Thresher victims of the 1979 threshing season at Delhi's Safdarjung Hospital

In early March, 1980, Dr. M. S. Swaminathan, the then Secretary to the Ministry of Agriculture, wrote to the chief secretaries of the concerned state stressing the need for *early* legislation to prevent the manufacture, sale and use of threshers without safety devices—as a long-term strategy—and administrative (such as compulsory registration of threshers) and educative measures for immediate implementation.

No doubt, the different departments have been pretty active but the proof of the pudding is in its eating. One would have expected the efforts of the committees to have led to action that would have resulted at least in a considerable reduction in thresher accidents if not their total elimination. But, alas, if this be the criterion, then

A drummy type thresher

G. K. Gorkha

these committees have thought it fit to consider the social rehabilitation of hapless labourers who have already been injured. For the poor labourers, the lack of functional values of the limbs makes all the difference between life and death.

These conclusions are further supported by the recent order of the Supreme Court on a Special Leave Petition (SLP No. 9097/79) delivered on 12 October, 1981 in the case of Balwant Singh and others vs. Mahmood, which arose out of a thresher accident. Justice P. N. Bhagawati and Justice V. B. Eradi suggested that the government should consider enacting some legislation for preventing the manufacture of threshers without adequate safety devices in order to protect the lives of landless agricultural labourers. In their view, "this is a social welfare measure essential to help the illiterate and poor farm labourers. There is no use telling them that there is a provision for compensation in the Workmen's Compensation Act. It is high time the government took steps in this direction". This in 1981, five years after the August 1976 Central Agricultural Ministry's letter to the Directors of Agriculture of the concerned States!

Stalled legislation

Both the legislature and the judiciary at the highest level seem to be interested in enacting suitable laws. One may, however, note that an Act, called the "Power Threshers Safety Act" initially drafted by the Haryana Government in 1979, is still gathering dust due to controversy over who should enforce it. The main feature of this proposed Act is a jail term ranging between 3 months and one year plus a fine of Rs. 1,000 for whoever manufactures, sells, or rents a power thresher made without a licence and does not conform to prescribed specifications and safeguards. There are, however, loopholes in the proposed Act. First, it does not lay down any punishment for those employers who force farm workers to work under unsafe conditions or under the influence of intoxicants. Second, the Act provides only for safe design *in the future*. It has nothing to say about the very large number of existing threshers which do not have any safety devices and their victims. It may be possible to bring the existing unsafe threshers under the purview of the law by invoking the Essential Commodities Act, but it is highly improbable that this can be enforced effectively given the large number involved.

Another important point is that of compensation to victims. As it is, the compensation recommended is meagre, Rs. 3,000, Rs. 5,000, and Rs. 10,000, respectively, for the loss of one arm, both arms, and loss of life. And even this provision of compensation has been done away with following legal objections. One might suggest that the employers insure all farm workers against accidents with a general insurance company which would be responsible for paying the compensation and that the rates of compensation be increased considerably. Here again, there are difficulties.

More important, as most of the farm workers are poor and illiterate, and also unorganised (unlike in a factory where unions of workers exist), it is doubtful that they will ever get the compensation laid down by the Act. Thus, while an Act will definitely improve the situation a bit, it will not have a significant impact on the problem of thresher accident victims.

Trading farm workers' safety

Let us now look into the technical aspects of the thresher problem. Most threshers are poorly designed and have no or inadequate provisions for safe operations; many are innovated and improvised by local artisans. Two years back, the ISI had formulated detailed guidelines for installations of power threshers and their operational conditions, but these are still not observed by the employers. The ISI has also adopted a Standard (IS: 9129-1979) which details the technical requirements for safe feeding systems for power threshers, but these, too, have not been incorporated by thresher manufacturers. There are two main reasons for this. The first is the considerable escalation of cost when safety devices are incorporated into the threshers. The second is the considerably decreased efficiency of operation; this is why the operators remove the safety devices. It should be noted here that all attempts made so far have concentrated only on the provision and elaborate designs of safety devices but have not considered the efficiency aspect. It is worth noting that the National Institute of Design, Ahmedabad, had designed a technically sound thresher and a prototype of it has also been developed at the Tractor Training Centre, Hissar. But, unfortunately, this has not yet been commercialised.

Such problems are not unique to threshers. They occur in agriculture, industry and other walks of life where poor, ignorant labourers are exploited and denied their due rights. The mere existence of a law is no guarantee that it will be obeyed. There are certainly Acts to prevent exploitation of child labour and to ensure payment of minimum wages to workers, but we know of gross violation of these acts and culprits going unpunished. After all, the enactment of an Act, the concern of the judiciary for the downtrodden and even the committee work of the executive are necessary but not sufficient conditions to prevent the continuing incidence of thresher accidents. The sufficiency criterion can be fulfilled only by: (i) the farm labourers getting organised, and (ii) the emergence of widespread social consciousness among the people who will rise to defend the rights of the victims whenever necessary.

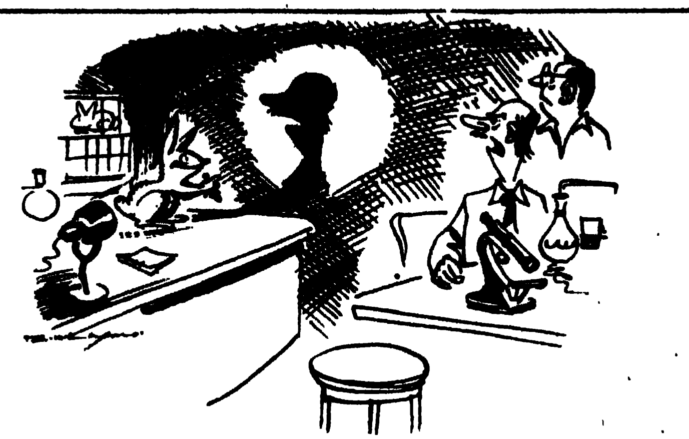
Thresher accidents in northern India are an example of a class of problems, where the introduction of technology leads to problems not necessarily because *technical* solutions are difficult or not available but because of a mismatch between the technology as it is applied and the social context into which it is introduced. The solution to such problems does not lie simply within the domain of technology or in the domain of law. It spills over, into moves which would drastically alter the current status of farm labourers—would-be-victims who will continue to get their arms chopped unless the use of unsafe threshers is completely stopped.

R. V. JASRA
K. P. KOTHIYAL

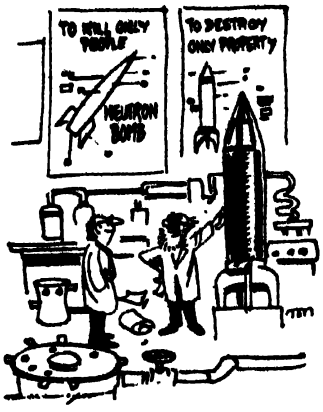
Mr. Jasra is a research scholar in the Chemistry Department and Dr. Kothiyal is senior research fellow in the Electrical Engineering Department at the Indian Institute of Technology, Delhi.

This World of Science!

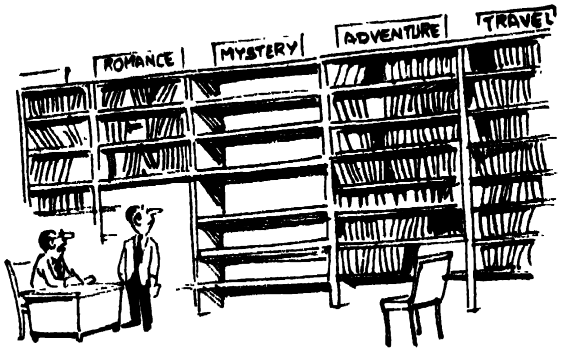
By R. K. Laxman



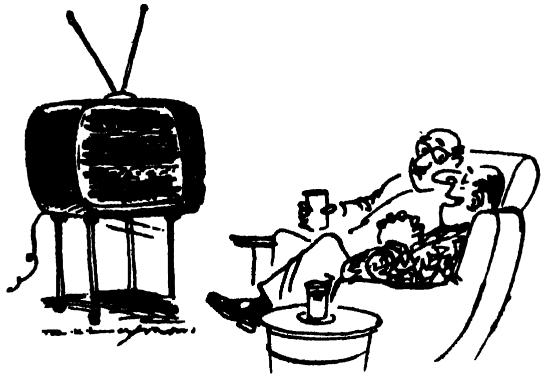
"I tell you, the discipline in this lab has gone from bad to worse."



"As a humanitarian, I have combined both the qualities in this—it will preserve the people as well as property."



"I've studied library science, but it's a mystery to me why the books in that section are never returned."



"I like to watch it—it's better than the programmes."

and of Scientists

[illegible] the first World War [illegible] the English scientist [illegible]

SCIENCE SHAPES LIFE

STDs HIGH IN THE GAYS

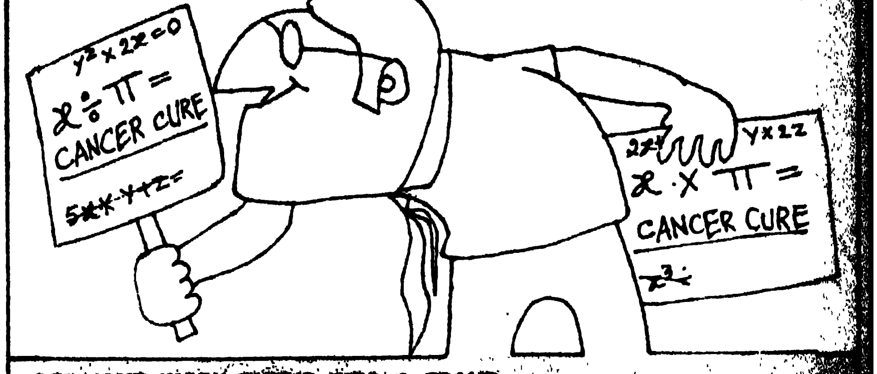
The hazards of being gay are many. Social mal-adjustments are well-known. Now recent studies indicate that homosexual behaviour is also associated with considerable personal and public health problems due to sexually transmitted diseases (STD). Gays face a greater risk than heterosexual persons (male or female) of gonorrhoea, syphilis, anorectal herpes simplex virus infections, and even for several STD's outside the traditional sphere of venereology like hepatitis A, B, amoebiasis, giardiasis, shigellosis and enteritis.

A fresh study was undertaken to find the frequencies of several STDs, in a large homosexual male population. Out of 4,212 respondents, 78 per cent experienced at least one episode of STD, while 60 per cent had other complications too.

These are pretty high figures by any count and no immediate viable solution is in sight. Hepatitis, at least, can be controlled through an immunisation programme, but for the other STDs there is no vaccine. Alternatively, education to restrict homosexual activity does not seem to hold out much hope. Perhaps only technically skilled and personally satisfactory health care services could do the job.

PETROL FROM NATURAL GAS

The New Zealand government, in collaboration with a US oil company, is setting up a one-billion-dollar plant in North Island, New Zealand. This plant will convert natural gas from off-shore fields to methanol and then to petrol. So far only South Africa has the process for making petrol from gasified coal. The New Zealand plant, the first one outside South Africa, also uses a more efficient process for making liquid fuel from the gas. Further commercial exploitation of this process should be a boon to those nations, which have no petroleum, but have abundant natural gas or coal. Perhaps, even the Bombay High gas may be converted into petrol.



BRILLIANT WORK TURNS INTO A FRAUD

The biomedical community, especially in the United States, is aghast with the fast turn of events in recent months. Their rising star, Mark Spector, with his 'golden hands', supposed to have an extraordinary gift for new tricky experiments, has crashed. Along with Professor Efraim Racker, he was even tipped off for a Nobel Prize for an excellent new theory of cancer causation. His scientific career now lies in ruins.

What went wrong? It seems Spector neither possessed a bachelor's nor a master's degree, but managed to enter Cornell in 1980 with forged data. He started work in Racker's laboratory and was assigned to purify an enzyme, sodium +/potassium ATPase. This enzyme is membrane-bound and pumps ions out of the cell by burning energy (converting adenosine triphosphate (ATP) to adenosine diphosphate (ADP) and phosphate). Racker long believed that one distinctive mark of cancer cells was in the inefficiency of this enzyme, but it was not obtained in pure form. Spector purified it in two months and further showed that it did work inefficiently in cancer cells. And he even found out the reason for the enzyme's inefficiency, by discovering and purifying a chain of other enzymes which act as signals and controls for the initial inactivation of ATPase in cancer cells. Excellent work by any consideration and all in six months time.

But, earlier in 1978, a cancer-causing gene (SRC gene) of the *Rous Sarcoma* virus was discovered to be causing cancer in cells infected with the virus. The gene produced protein kinases that were believed to phosphorylate the amino acid tyrosine. Till the eighties, however, all other amino acids were phosphorylated by the known kinases but tyrosine was not.

Spector dramatically announced that it was tyrosine which was phosphorylated by his kinases. Things started to fit in the jig-saw puzzle and it seemed there was a unified theory for cancer causation—a cell is infected with a tumour virus, its SRC gene produces a kinase which suddenly triggers on the chain of other kinases. The last kinase phosphorylates the sodium +/potassium ATPase of the membrane, making it inefficient and hence initiating changes which make a cell cancerous.

Then Volker Vogt, a tumour virologist at the Cornell University, was considerably intrigued—perhaps more from frustration than curiosity. And in a continuous attempt to reproduce Spector's work, he found that the whole work was nothing but a big fraud, where proteins of similar molecular weight had been interchanged! Of course, Racker immediately withdrew the papers from the press, and got rid of his 'brilliant' student. Now he is busy trying to find out how much of his theory is true or false.

METHANOL AS AIRCRAFT FUEL

Another potentially good news for countries facing petroleum shortage is a two-man campaign being carried out in the USA to demonstrate the feasibility of methanol as an economic fuel for aeroplanes. That aeroplanes can run on methanol has been known since 1967. Gordon Cooper, one of the earliest US astronauts, flew an air force jet on methanol. The snag, however, was that methanol gives only half as much energy as hydrocarbon fuels. This appeared to rule out methanol purely on grounds of aircraft weight. However, Cooper and his partner, who was Reagan's personal pilot for two years, say that if aircrafts fly high enough, methanol is no longer an inefficient fuel. Something happens to it, and they know not what!

So far, the aviation industry had been sceptical about their claims. But now, because of Cooper's personal prestige as a former astronaut and his partner's acquaintance with Reagan, methanol is being seriously considered as a fuel.

ISLAMIC AND SOCIALIST SCIENCES

Iran's Jihad-e-Daneshgahi (University Jihad), a seven-member council set up by Ayatollah Khomeini's government, claims to have created an Islamic education system suited to Iran's needs. The actual contents of the new system will be known only when Iran's universities, which have been closed for the last one year, reopen. But it is clear that the emphasis, at least in science and technology (S and T), will be on applied research required for Iran's needs.

[illegible] MALARIA

Malaria is rearing its head again in the developing countries: this, a report says, is a consequence of the green revolution which necessitated heavy pesticide use. A recent study by G. Chapin and R. Wasserstrom of Columbia University is critical of the different programmes undertaken in the Third World by some international agencies. This study has caused considerable embarrassment to these agencies; an attempt was even made to stop publication of the research work from Columbia University. And though the UN convenes a meeting annually or biannually to formulate pesticide use policy, there was no change in the policy after the results of Chapin and Wasserstrom were known. Wasserstrom says, "I don't think we are in a position to say that the UN simply kowtows to the chemical companies. But it comes pretty close to that."

But, today the situation has changed dramatically. Malaria is back with us, primarily because the *Anopheles*-mos [illegible] ing to the researchers, use of pesticides for public health by itself need not have caused the collapse of the global malaria eradication programme. The increasingly heavy and indiscriminate use of the chemicals in agriculture is responsible for the widespread resistance, since high yielding varieties of crops require a lot of fertilisers and pesticides to produce a bumper harvest. Besides, the heavy investment they require, we have proof of their seriously upsetting the ecological balance. Large amounts of pesticides released into the environment tend to increase resistance among mosquitoes by 80 per cent. It may be stated that there were always a few who had serious reservations about the green revolution.

The Columbia research team wants to increase public awareness about the ineptness of the UN agencies in handling public health problems of developing countries. They also plan to study the resurgences, if any, of other parasitic diseases.

I AM SIXTY GOING ON..

STAY YOUNG AND HEALTHY

Aging has its biological markers: normally the predictable physical and behavioural changes during the aging process. In rodents, one marker is a decline in immune function, accompanied by loss of memory. In humans, a perceptible loss in hearing and vision, cardiovascular changes, bone loss, sleep variations and also a decline in immune functions are all markers.

Biomarkers have been known since many years. But now, it seems, they are indicators of the effectiveness of some intervening agents and provide room for manipulations to keep young. If a specific agent delays the onset or further progression of a biomarker, then it holds promise as a potential tool for keeping young and healthy.

But all biomarkers are not equally effective indicators. They should be reproducible, manifest themselves in many species, change significantly with age, and be inexpensive to evaluate

SWIMMING POOLS BREED VIRUSES?

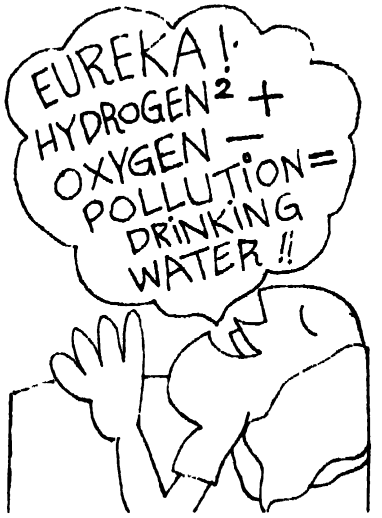
Throughout the world, swimming is a joy for millions, but many times different infections and illnesses beset swimmers. More prominent amongst these are ear infections (otitis externa), a skin disease caused by the bacteria *Pseudomonas impetigo*, shigellosis (a form of dysentery), and primary meningoencephalitis (infection of the membranes of brain). To further add to the woes of swimmers, now there is direct evidence for transmission of viral infections by swimming pools.

D'Angelo, Sagar Goyal and colleagues from the Department of Virology and Epidemiology, Baylor College of Medicine at Houston, Texas, USA, isolated from water samples of swimming pools, a virus that causes pharyngoconjunctival fever. They also observed a statistically significant relationship between swimmers in swimming pools in municipal areas and gastrointestinal illnesses. Significantly, all the municipal pools had filtered, chlorinated water!

Viruses enter the pools through fecal material and nasal and pharyngeal secretions. The number and dispersal of these materials, the presence of solids, disinfectant used, the sunlight, the filtration, pH and temperature of water and the inherent resistance of viruses themselves—all determine the survival of viruses in the pool. Effective chlorination depends on the dose and form of chlorine. Free chlorine is more effective than the various combined forms; a level of 0.4 part per million of free residual chlorine is considered [illegible] for disinfection.

The study, however, indicated that these levels are neither maintained nor adequate. Several substances like soil, urine, ammonia and dirt tend to react with chlorine to form chloramines and render it less active. Different organic solids also protect the viruses to some degree from chlorine. Additionally, poor operations and faulty equipment also contribute to low chlorine levels. Therefore, it seems, even in the west new standards will have to be laid out for effective disinfection. But there is one drawback—high chlorine levels lead to eye irritation! Statistics in India, where public health norms are indeed lax, is anybody's guess.

OF DREAMS AND DREAMING


EUREKA! HYDROGEN² + OXYGEN — POLLUTION = DRINKING WATER !!

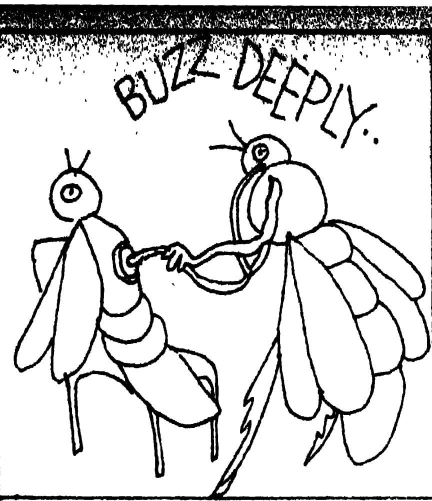
Dreams can be lucid or non-lucid. People have even been known to solve problems in their dreams. For example, Kekule, the organic chemist solved the structure of benzene in his sleep. Coleridge composed the famous 'Kubla Khan' in his dream. In the non-lucid dreams, however, the dreamer may not be aware of the various events in the dream. On waking, he may accept the nonsensical nature of the dream and forget about it completely. This is not true of lucid dreams, where the dreamer is perfectly aware of the dreams he is seeing. He can even control the content of the dreams. And, like the director of a play, decide about its course of action.

Lucid dreams, according to a recent study, perform functions which lead to better understanding of memory, perception and personality. Perhaps, more information can also be obtained about certain aspects of brain functions. In addition, lucid dreams could be a source of relaxation and enjoyment too. What is not achieved in reality can at least be experienced in dreams. The scientists may apply this state in therapy of phobia-prone individuals by providing realistic settings for self-therapy.

These needs apparently include insulin, vitamin B and dapsone. Teheran University has already started work on making these. Efforts are also afoot to take science to the villages under the new programme. Local ingenuity and innovation will be emphasised at all levels, and dependence on outside help discouraged. However, the mullahs will not deprive diabetics of the insulin of western origin!

While Iran will use Islamic backing for its S and T policy, the new Government of France under Mitterand is planning a democratic debate to find socialist answers for its research policy. This debate will be held in January 1982 at a huge conference, preparations for which have already started. The debate will cover the entire gamut of France's research and technology strategies, including its political, social and economic implications, ethical problems and the relative importance of basic and applied research. Other topics to be covered include impact of research and technology on industry, health, working conditions, etc.

The major objective of the debate is to take away science policy making from a group of elitist bureaucrats and involve experts from all over the country in the exercise.


BUZZ DEEPLY.

BEE CLINIC

Now, we have bee doctors to treat sick bees. A diagnostic clinic has been set up at Beltsville, USA, where disease-infected honey-combs, mailed by beekeepers and apiary inspectors, are routinely checked. Bees have a direct role in agriculture as they help in pollinating flowers. Any reduction in pollinated flowers naturally decreases agricultural production.

The honey-comb sections are examined under microscopes for spores or possible parasites or bacteria known to cause bee maladies.

GENETIC ENGINEERING—NO MORE GUIDELINES

When scientists first invented the technique of transferring DNA-based genetic information from one species to another there was a general concern that breaking the natural species barrier may lead to creation of uncontrollable, monstrous new organisms. Conscientious molecular biologists, led by Paul Berg, who had done pioneering work in developing this new technique of gene splicing, initiated a public debate on the issue. They called for a moratorium on further research in this area, until the potential risks had been assessed in detail—an instance when biologists recognised their social responsibilities of the consequences of their work.

The result was detailed guidelines for research in recombinant DNA. Guidelines developed by the National Institutes of Health (NIH) USA, provided the model for most nations. These guidelines, though they did not have the force of law, were mandatory for all dependent on government grants.

Last month the NIH took a step which should lead to the virtual dropping of the guidelines. The Recombinant Advisory Committee (RAC), for all practical purposes the decision-making body, has recommended that the guidelines should be made voluntary, as in private enterprise, even for experiments carried out with government grants. If the Committee's proposals are formally accepted, most experiments will no longer require prior approval of the NIH. Also, no prior approval will be needed for scaling up the experiments beyond the laboratory scale and releasing into the environment organisms containing recombinant DNA. Universities conducting recombinant DNA experiments will no longer need to have their own biosafety committees.

Recombinant DNA, an example when scientists publicly recognised their responsibility about the impact of their work on society, has also ironically proved that the scientific community, at least in the West, is now moved more by profit motive then by conscience. The evidence has been steadily accumulating over the last few years.

Recently, at a meeting organised by Cogene — the Committee on Genetic Engineering — a subcommittee of the International Council for Scientific Unions, in Rome, to discuss the impact of commercialisation of the technique, most of the 100 molecular biologists from all over the world were quite unconcerned about the threat of private money to their science. Most knew that researches in genetic engineering will be increasingly dependent on money from industry, but they were not bothered about the implications of this. And the few who were concerned were quite bitter about this indifference.

BOOM OF SCIENCE JOURNALS

Today we have more journals to be read than can be read. And yet, scientists are constantly complaining of having to find out newer outlets to get their work published. Of course, science is becoming highly specialised and there is a torrent of discoveries.

The new publishers are, therefore, responding to a demand of the scientific community. Some of the new magazines may disappear fast; others, perhaps, may manage to last and evolve a pattern of their own. It's all to be seen. The October 1981 issue of *Nature* gives readers an idea of the new journals that have appeared over a period of 3[illegible] months ending about a year ago.

In China too, there is a spurt in scientific journals. There it is linked to changes in government policy on science and the direction of scientific development. China wants to make rapid advances in defence, agriculture, industry and science and technology. The modernisation of science, among other things, involves publication of science magazines, for all different age groups.

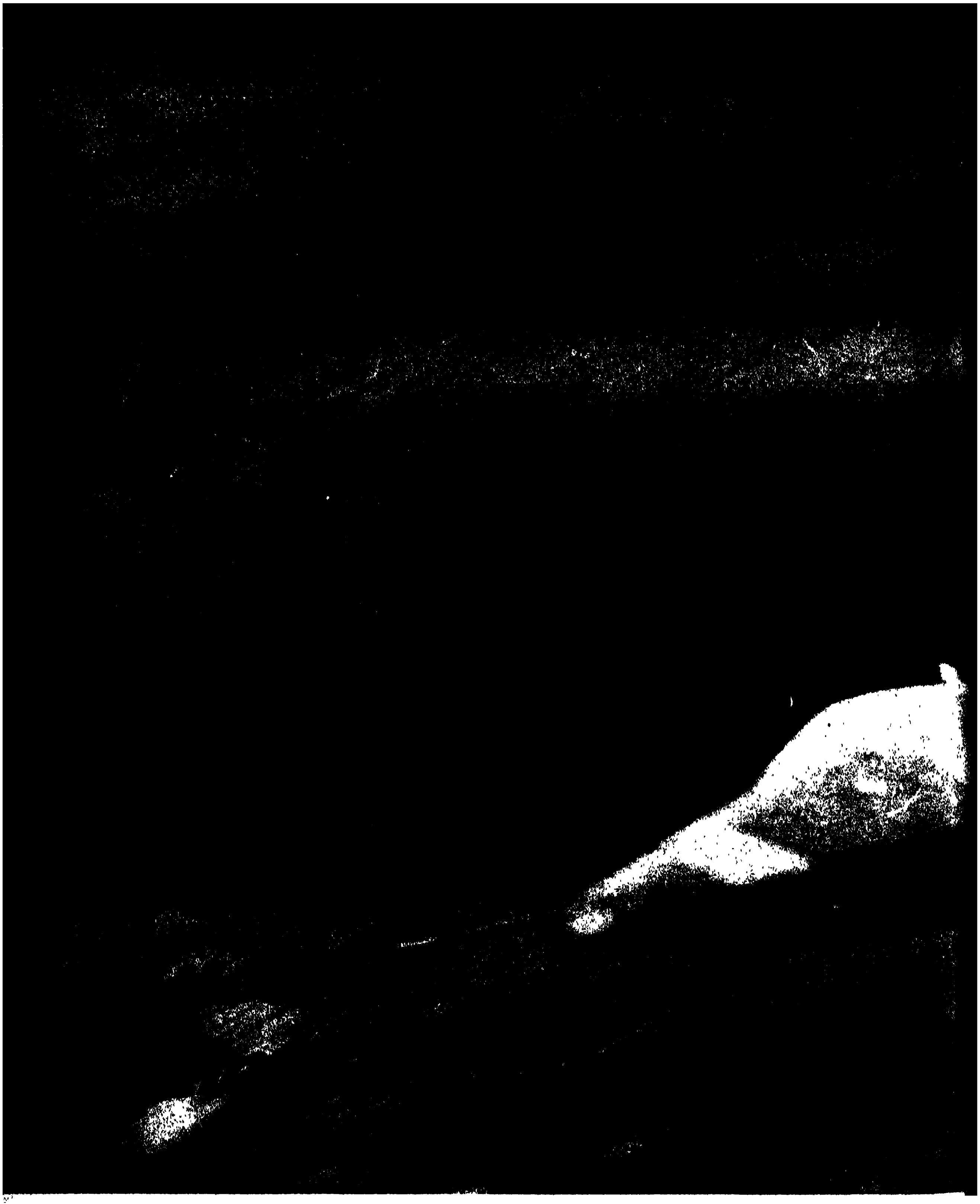
Western journals are also translated, and the standards of translations are high. But, ironically there is a dearth of well-trained scientists and technicians for implementation of the modernisation programme. Can the science journals fill this gap?

ARE ACNE JUST SKIN DEEP?

Those pimply papules pustules, or acne as they are scientifically called, have scarred many a smooth cheek, and evaded a real solution till now. Beauticians and clinicians regard them as a purely dermatological or, skin problem—but recent research indicates that acne may not be just skin deep.

There may be a link-up between severe acnes and some endocrinological disorder, as discussed recently at the Endocrine Society Meeting at Cincinnati, USA. Endocrine (ductless) glands produce hormones, specific substances regulating many metabolic functions of an organism. Radioimmunoassay (RIA) techniques have made it possible to detect subtle changes in serum testosterone (male hormone) levels. This fact was used in studying possible hormonal changes in women afflicted with acnes. Of the 139 women studied, 90 per cent had above average plasma testosterone levels, and 97 per cent even exhibited male-type hair growth pattern in different parts of the body. Also, though 39 per cent had regular menses, 19 per cent exhibited irregular periods. But, what about those of the fair sex who have nothing—no hairiness, no irregular periods—but just acne?

Past studies indicated that oestrogen (a female hormone) resulted in reduction of acne formation.



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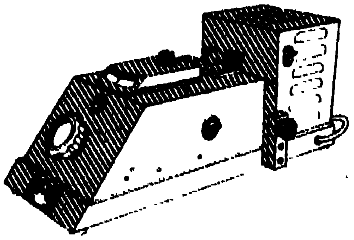

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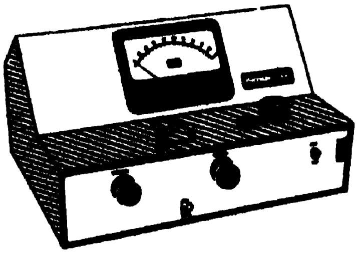

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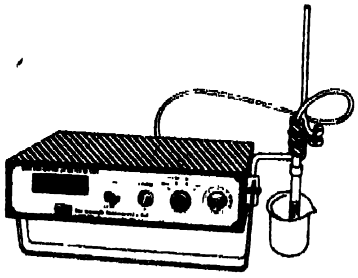

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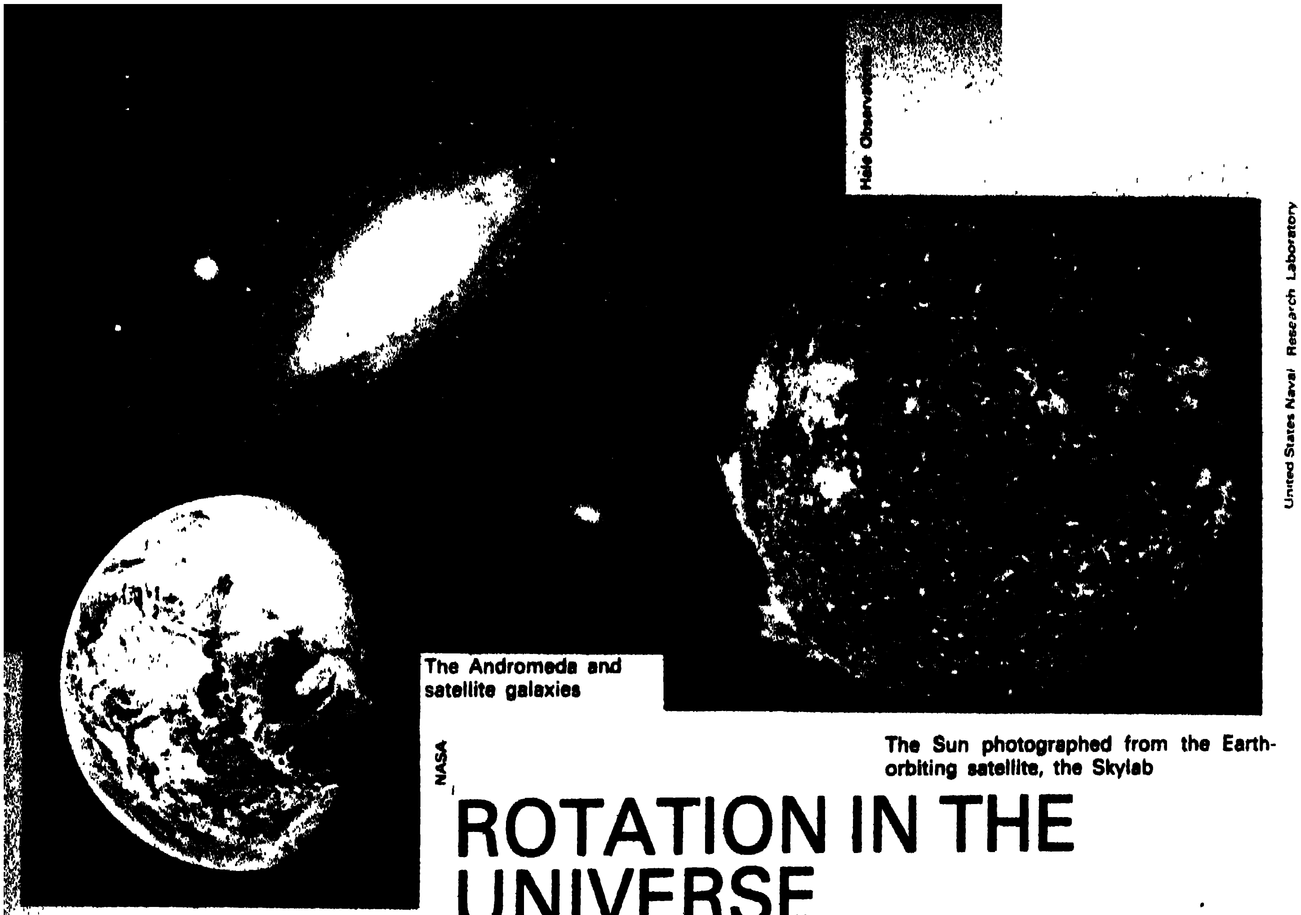

Hale Observatories

The Andromeda and satellite galaxies

United States Naval Research Laboratory

The Sun photographed from the Earth-orbiting satellite, the Skylab

NASA

The Earth as photographed by the Apollo 16 astronauts

ROTATION IN THE UNIVERSE

P. P. Divakaran

The atoms spin, so do the planets, stars and galaxies... and maybe even the universe

ALL of us have read the (probably apocryphal) story of how the basic idea of the law of gravitation was, so to say, knocked into Isaac Newton's head by a falling apple. We also know of another APPLE (the Ariane Passenger PayLoad Experiment) which, unlike the ripe fruit which fell on Newton's head, has been sitting "up there", immobile, for the last few months. The law of gravity says that any two material bodies attract one another by a force proportional to the mass of each of them and to the inverse of the square of the distance between them. The acronymic fruit of ISRO's labours is of course a very material body and is no exception to the universal law of gravitation. What keeps it as well as our natural satellite, the Moon (and a large number of artificial satellites). from falling to the Earth is a force called the *centrifugal force*, which cancels the gravitational attraction of the Earth on them—and this force arises directly out of their approximately circular motion around the Earth Exactly the same phenomenon works to keep the planets and the countless bits of matter known as the asteroids in stable orbits around the Sun.

Contrary to the popular notion promoted by the story in school books, between the apple brought down by the Earth's gravitational pull and the planets in their everlasting orbital motions, there lies the other of Newton's great contributions to the science of mechanics, the laws of motion. The law of gravitation pertains to only one of a number of distinct forces that are now recognised to act between pieces of matter. The laws of motion, in contrast, are more abstract and are applicable to all motion, not only that influenced by the force of gravity (we say that the laws of motion fall in the realm of *kinematics*, while the law of gravity describes (part of) the *dynamics* of material bodies). These laws begin by defining a force as that which causes deviation from motion with a uniform velocity vector. In the absence of an external force, a mass point or a rigid body will continue to move along a straight line and with unchanging speed. The second law of motion then quantifies force by postulating that it is the product of the mass and the acceleration (the rate of change of the velocity) produced by it. It is worthwhile noting that a minor modification (substituting the quantity mass × acceleration in the second law by the rate of change of momentum) is sufficient to ensure the validity of the two laws of Newton in the context of the special theory of relativity.

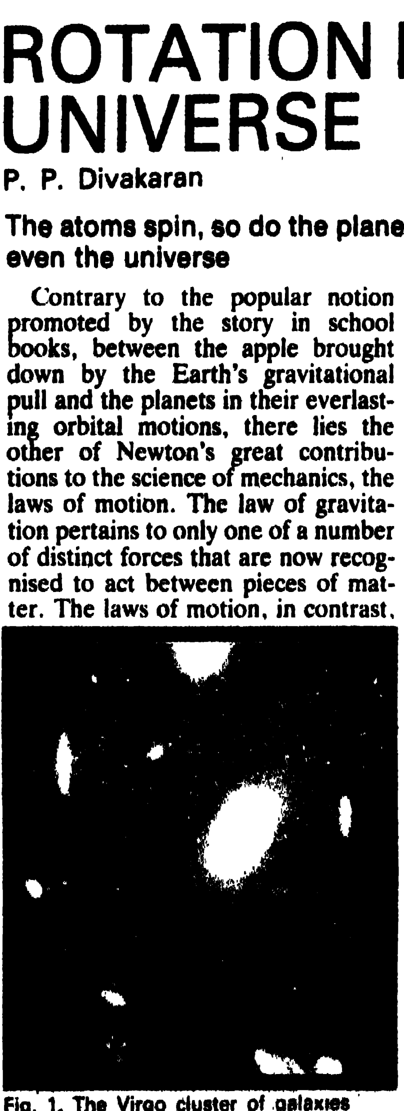

Fig. 1. The Virgo cluster of galaxies

Kitt Peak National Observatory

In trying to understand the orbital motion of a satellite around the Earth (or that of planets around the Sun, etc), it is useful to make two idealisations; (i) that the orbits are circular (in reality, they are ellipses),

Fig. 2. Comet Humason in 1961

Hale Observatories

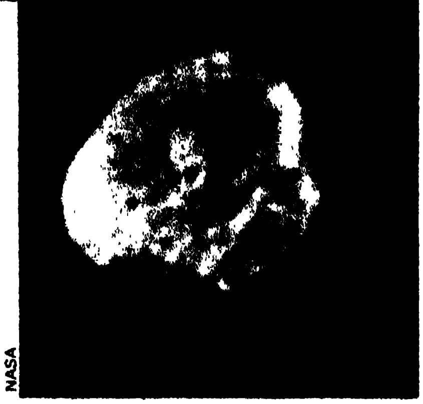

Fig. 3. A closeup view of Saturn's irregular, disc-shaped satellite Hyperion obtained by Voyager 2 spacecraft on 24 August from a distance of about 500,000 km

NASA

and (ii) that the satellites as well as the Earth have all their respective masses concentrated at their centres of mass. These simplifications are made for ease of picturisation. The mathematical theory deals equally satisfactorily with elliptic as with circular orbits. Similarly, it is possible to show that the resultant force of gravity between the bits of matter that make up two extended, spherically symmetric bodies is the same as if their entire masses are placed at their respective centres. The velocity vector at any point on the orbit then points along the tangent to the orbital circle at that point. Since, even for constant speed of revolution, this vector changes (in direction) with time, turning through 360 degrees in one revolution, the revolving body is subject to an acceleration and, by Newton's laws of motion, to a force pointing radially outwards. This force is the *centrifugal force* and will tend to pull the satellite farther away from the Earth. But the gravitational force exerted by the Earth acts oppositely, pushing the satellite in. Whether the satellite remains in, or attains a stable orbit or falls to the ground is fully determined by whether the centrifugal force (which increases with increasing angular speed, the rate at which it is revolving) wins over the gravitational pull (which decreases with increasing distance from the centre of the Earth). In the case of APPLE, not only is the orbit stable, its angular speed is precisely the angular speed of the Earth's spin so that it appears to be stationary over a fixed point on the Earth. Readers will recall newspaper accounts of the delicate orbital manipulations that were performed by ISRO to bring about this matching (SCIENCE TODAY, September 1981, p. 65).

Since the universe we are part of is not one-dimensional, rotary and spin motions are ubiquitous and have manifestations at all levels and scales—from the elementary constituents of matter to the largest agglomerations physics can deal with, extending perhaps even to the whole cosmos. Some parts of this vast realm still remain mysterious and intriguing (Fig. 5). But the greater part of this territory is so familiar to every student of physics that the intellectual struggle that led to these conquests tends to lose its romance. The following articles in this issue and the next on some aspects of the large-scale phenomenology of rotation are meant partly as a remembrance of things long taken for granted, and partly as ambitious and occasionally speculative peeps into the mysterious domain that still remains unconquered. It must not be forgotten, for example, that there is still no universally accepted picture of the origin of the solar system, even though the dynamical principles of the motions of the planets have been fully understood a long time ago

The basic concepts

Clearly, the response of a body to forces which cause it to revolve or rotate depends on how rigid it is. A perfectly rigid body can be taken to be one which is impervious in shape and size to any stress applied to it. The elementary principles of rotary or spin motion are best introduced by reference to a rigid body (in real systems, deviations from rigidity can be significant, ranging from the slight flattening of the Earth at the poles, caused by its spin, to the chaotic movements of fluids that form stars). Now, it is a theorem (due to the mathematician Euler) that the most general displacement of a rigid body is a translation, or a linear displacement without change of orientation, followed by a rotation, or an angular displacement about an axis (to those who may consider this to be self-evident, I offer the remark that it would not be true if the dimensionality of space were greater than three). A motion of a body is a prescription of its displacement from a fixed position as a function of elapsing time. Euler's theorem then allows us to decompose the general motion of a rigid body into the motion of its centre-of-mass (which may in particular be a revolution about a point outside the body) and into a spin motion about an axis passing through the centre-of-mass—the axis itself may undergo a change of direction with time (for a familiar example, see Fig. 6). Occasionally, there are correlations, *a priori* unexpected, between the two types of motions as in the case of the Moon whose spin and orbital periods are the same (see Rotation of Earth, p. 24).

The study of spin by itself, of matter on a microscopic scale (molecules, atoms, ..., elementary particles) where quantum effects become all important, has been a source of some of the most profound ideas of 20th century physics. But, at the classical, macroscopic level, spin and revolution involve essentially similar concepts and can be discussed together using common terminology. Let us consider the simplest example of a point mass with a mass m in uniform revolution around an axis at a distance r from it, with a period of revolution T (Fig. 7). The angular speed is then $2\pi/T = \omega$ and the linear speed is $2\pi r/T = v$, so that $v = r\omega$. Just as v is the magnitude of the

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Fig. 4. Cyclones occur on other planets too, as they must as long as the planet rotates and has an atmosphere to support winds. This Voyager 2 photograph shows a cyclone over the northern region of Saturn. (The bright spot in the centre of the cloud at far left.) Since this is a view taken from outside the planet (from "above"), allowance has to be made for a change in the sense of the circular motion from what is described in the text for the Earth as seen from "below"

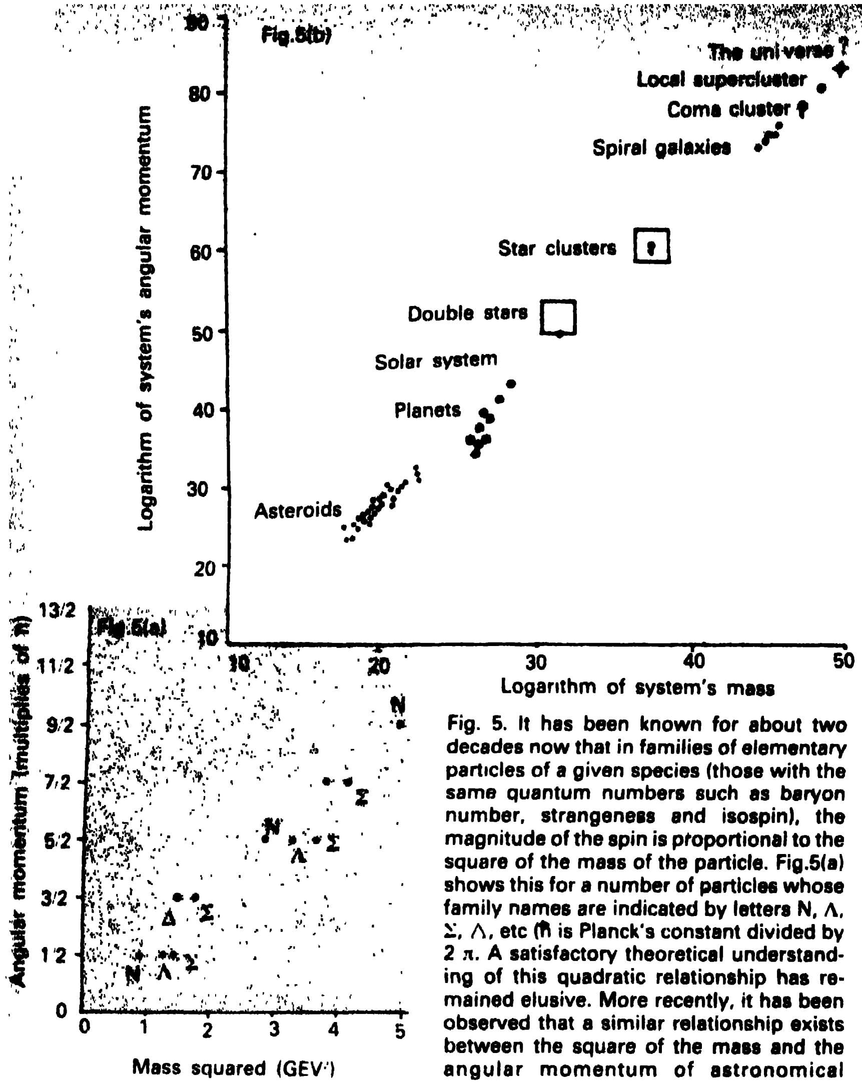


Fig. 5. It has been known for about two decades now that in families of elementary particles of a given species (those with the same quantum numbers such as baryon number, strangeness and isospin), the magnitude of the spin is proportional to the square of the mass of the particle. Fig.5(a) shows this for a number of particles whose family names are indicated by letters N, Λ, Σ, Λ, etc (ℏ is Planck's constant divided by 2 π. A satisfactory theoretical understanding of this quadratic relationship has remained elusive. More recently, it has been observed that a similar relationship exists between the square of the mass and the angular momentum of astronomical bodies, within the rather large uncertainties with which these quantities are known. See Fig.5(b)

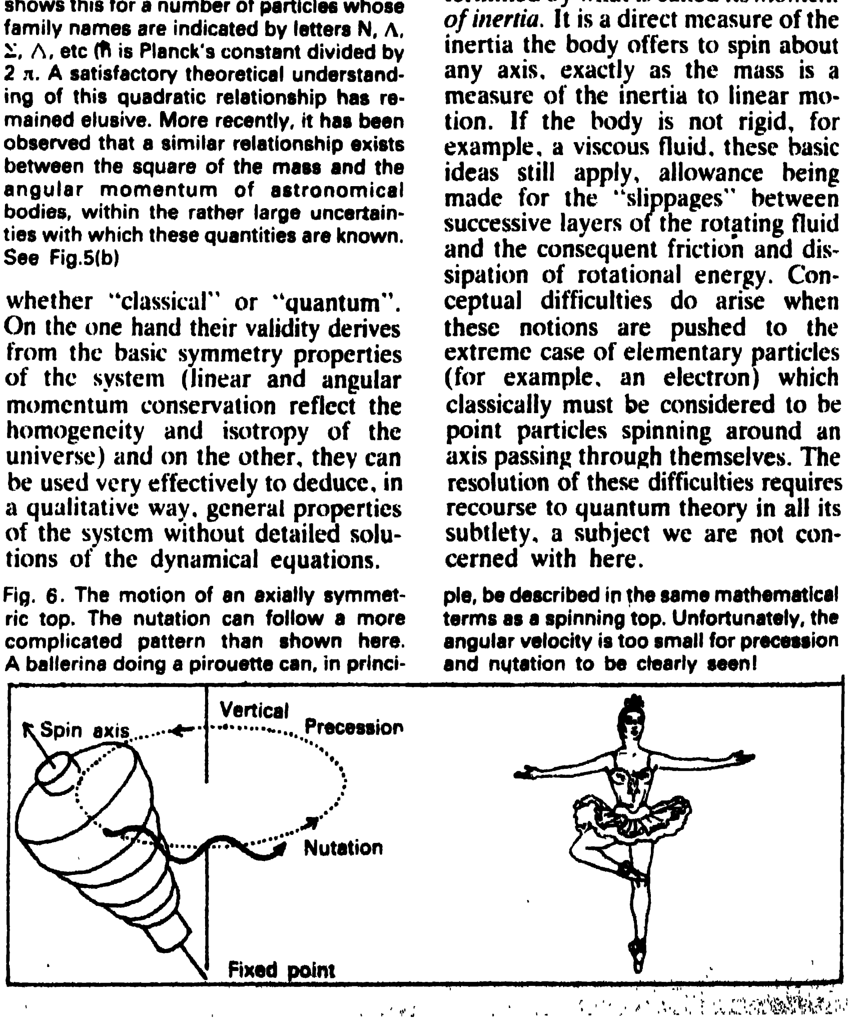
velocity vector $\vec{v}$, ω can be taken to be the magnitude of a vector, the *angular velocity* $\vec{\omega}$. In 3-dimensional space, the only vector such that its magnitude is v/r is necessarily perpendicular to both $\vec{v}$ and $\vec{r}$ (the radius vector). Since $\vec{v}$ is tangential, it follows that the angular velocity is a vector which points along the axis of revolution.

An even more basic concept is that of *angular momentum*. It is also a vector perpendicular to $\vec{v}$ and $\vec{r}$ and therefore parallel to $\vec{\omega}$ and the axis, but with a magnitude equal to $mvr = mr^2\omega$. The reason why the angular momentum is such a fundamental quantity is that, in the absence of any external forces acting on m, it remains constant in time, in direction and magnitude: the angular momentum is "conserved". The situation here is quite similar to linear motion: Newton's first law can be stated as the conservation law of momentum $\vec{p} = m\vec{v}$ in the absence of an externally applied force. Conservation laws such as these are central to modern methods of study of the behaviour of dynamical systems of all kinds, whether "classical" or "quantum". On the one hand their validity derives from the basic symmetry properties of the system (linear and angular momentum conservation reflect the homogeneity and isotropy of the universe) and on the other, they can be used very effectively to deduce, in a qualitative way, general properties of the system without detailed solutions of the dynamical equations.

Not all forces are capable of changing the angular momentum. In the example above, for instance, a force in the direction of the axis cannot affect rotary motion at all and one along the radius vector cannot affect the angular momentum. To be able to do that, a force must have a tangential component and such a force is a *torque*. Apart from purely mechanical methods such as are employed in rotating machinery, a torque can arise in a number of other ways: gravitational force on a body whose mass distribution is not spherically symmetric (for example, the Earth with its flattened poles, the action of a magnetic field on a spinning body which is also electrically charged, etc). Such torques are important in the motions of astronomical bodies as will be abundantly clear from the succeeding articles.

The passage from the mass point revolving around an external axis to a spinning rigid body is conceptually straightforward. We can imagine a rigid body to be a set of mass points, filling a region surrounding the axis and keeping mutual distances between such mass points fixed. Given such a mass distribution, its characteristic rotational properties are determined by what is called its *moment of inertia*. It is a direct measure of the inertia the body offers to spin about any axis, exactly as the mass is a measure of the inertia to linear motion. If the body is not rigid, for example, a viscous fluid, these basic ideas still apply, allowance being made for the "slippages" between successive layers of the rotating fluid and the consequent friction and dissipation of rotational energy. Conceptual difficulties do arise when these notions are pushed to the extreme case of elementary particles (for example, an electron) which classically must be considered to be point particles spinning around an axis passing through themselves. The resolution of these difficulties requires recourse to quantum theory in all its subtlety, a subject we are not concerned with here.

Fig. 6. The motion of an axially symmetric top. The nutation can follow a more complicated pattern than shown here. A ballerina doing a pirouette can, in principle, be described in the same mathematical terms as a spinning top. Unfortunately, the angular velocity is too small for precession and nutation to be clearly seen!



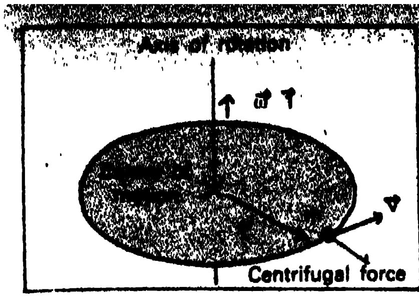


Fig.7. The basic quantities pertaining to circular motion. As long as m is constrained to move in the indicated plane, the angular momentum can change only in magnitude, through the application of a torque in the same direction as that of $\vec{v}$

It should not be surprising that the complete dynamical description of a rotating body can be, except in the simplest cases, very complicated. Even the study of the motion of a spinning top, whose mass distribution is symmetric about its spin axis and which has one end of the axis fixed, is not elementary. The complete solution of this problem, which can be taken to be the prototype of a number of situations of astronomical interest, leads to the picture illustrated in Fig. 6 In addition to the rapid spin about the axis, the axis itself describes a cone around the vertical direction, its upper end drifting around in an overall circular motion' called *precession*. On this precession is superimposed a wobbly up-and-down motion called *nutation*. All these motions are easy to follow in a toy top and have rough analogues in the spin of the Earth.

Back to APPLE

To a very good approximation, the examples given above can be considered to be of motion in the absence of a torque; that is, they are angular-momentum-conserving motions. It is instructive in such cases to try and understand the qualitative properties of the motion, as far as possible, from the conservation laws alone. Let us look again at the movement of a satellite around the Earth or of a planet around the Sun from this viewpoint. We saw earlier that the angular momentum of a satellite is a vector perpendicular to its orbital plane, having a magnitude l = mvr. It follows from the conservation of l that the orbital plane remains the same in space, so that as the Earth rotates beneath it, the satellite passes over different points of the Earth. If the orbital radius, r, of the satellite is changed, say, by firing a rocket on it, its linear speed v will change in inverse ratio so that vr remains the same (m does not change appreciably). If r becomes too small, the Earth's atmosphere will come into play, offering frictional resistance to the motion of the satellite, reducing r and increasing v still more and thus increasing the frictional drag till, ultimately, the satellite is burnt up or falls to the ground as did the Skylab. For a geostationary satellite like APPLE, the orbit has to be "fine-tuned" in two different ways: firstly, the perpendicular to the orbital plane must be in the same direction as the Earth's spin axis so that the satellite passes over the same latitude always and, next, the period must be adjusted to be the same T = 2π/ω as the Earth's spin period of one day. This can be done by simply changing the orbital distance as indicated above, thanks to the angular momentum itself remaining constant.

It is easy to find many examples around us of the use of spin to stabilise motion. Virtually all of this can be understood in terms of the conservation law of angular momentum. The interested reader might wish to challenge himself or herself by wondering about such things as the balancing of a bicycle, the rifling of a gun-barrel, the hovering motion of a frisbee, etc in this way. As the articles which follow make clear, even in such 'advanced' scientific contexts as the movement of heavenly bodies, a great deal of insight is provided by purely qualitative reasoning of this kind.

Finally, the fact that circular motion necessarily is accelerated motion has one major conceptual consequence. In describing linear motion, with uniform velocity, we have the choice of the appropriate frame of reference in which to study the motion. Evidently, if a particle moves with a uniform velocity as seen by one observer, it does so with respect to any other observer who himself moves with uniform velocity with respect to the first. Consequently, the description of the motion does not depend on the observer as long as all observers are in mutually inertial frames, that is, they move with uniform velocities with respect to one another. This "principle of relativity" does not hold for two observers whose movements include a mutual rotation: rotating coordinate frames are not inertial. Since Newton's laws of motion are valid only in inertial frames, the description of the motion of a particle as seen by a rotating observer like one on the Earth requires a passage from an inertial frame (for practical purposes, a frame fixed with respect to the distant stars) to the non-inertial Earth-fixed frame. In particular, a force-free motion in an inertial frame will be an accelerated motion if seen from the rotating Earth. This acceleration can be shown to be perpendicular to both the velocity of the particle and to the angular velocity of the Earth. It is called the Coriolis acceleration and is often considered as due to the action of a force called the Coriolis force. In spite of its origin in rather fundamental and abstract distinction between inertial and non-inertial frames, the Coriolis acceleration is a very real phenomenon and is responsible for such facts as the circular air currents in a cyclone which are anticlockwise (as observed from "below") in the northern and clockwise in the southern hemisphere.

NASA

Fig. 8. This series of Voyager 2 pictures of Tethys shows its distinctive large crater, 400 km in diameter, as it rotates. These images were obtained at four-hour intervals beginning late 24 August and ending early the next day. The rotation indicated by the position of the crater is real and not due to the changing camera angle

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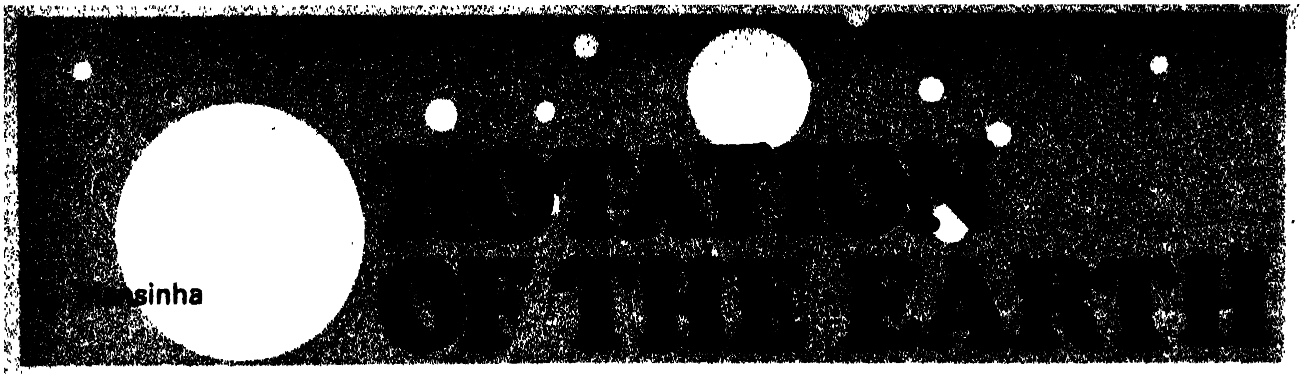


ROTATION OF THE EARTH

sinha

Due to the pull of its ultra-large attendant, the Earth's spin has been slowing down for the last billion years, and our days are becoming longer

A REMARKABLE fact about the planets and asteroids that orbit the Sun is that, with a few exceptions, their rates of rotation do not vary very much from a median value. The spin rates of the planets range from about 9.8 hours (Jupiter) to about 24.6 hours (Mars). The periods of rotation of Jupiter, Saturn and Uranus are all essentially equal, about 10 hours. This near-uniformity of the spin rates is all the more remarkable as the ratio of the mass of the smallest asteroid to the largest planet is about 10^{11}. For most of the planets it is believed that the spin rate has remained constant since the final stages of formation of the solar system. One planet, with which we are very familiar, is an exception to the rule and has been slowing down steadily for at least the past one billion (10^9) years or so. That planet is the Earth. The Earth is also otherwise unique in possessing a comparatively large satellite, the Moon. The ratio of the mass of the Moon to the mass of the Earth amounts to 1.2 per cent. No other satellite-planet pair in the solar system has as high a ratio. Due to the presence of the Moon, the Earth's spin rate is decreasing. Due to its proximity, the Moon is locked on to the Earth so that at present the Moon's period of rotation is equal to the period of revolution around the Earth. In fact, most of the satellites in the solar system have spin periods equal to the orbital period.

The slowing down of the Earth is just one of several phenomena (associated with the rotation of the planet) that are of astronomical and geophysical interest. The axis of rotation of the Earth moves in space with respect to distant stars. This motion of the Earth's axis is known as precession and was first reported by the astronomer Hipparchus in the second century BC. The explanation of precession had to await the development by Isaac Newton of the theory of gravitation. Precession is caused by the attraction of the Sun and the Moon on the equatorial bulge of the spinning Earth. A second phenomenon involves motion of the entire Earth with respect to the rotation axis. This is known as the "wobble", and was predicted by the mathematician Leonhard Euler in 1765, and finally detected by Seth Carlo Chandler in 1891. Viewed from our vantage on the surface of the Earth, the wobble appears as a motion of the Earth's rotation axis within the Earth.

We will discuss these and other aspects of rotation in turn. The change in the rate of rotation is not difficult to comprehend. An insight into precession may be obtained by observing the ordinary top. The wobble is somewhat more involved, but can be visualised through a few simple kitchen-type experiments, to be described later on in this article. But, first, a few brief definitions of the terminology used. They will make the subject clearer.

The two points where the rotation axis of the Earth emerges at the surface are the north and south rotation poles. The motion of the rotation axis within the Earth is equivalent to stating that the rotation poles move on the surface of the Earth. Note that the motion of the rotation axis within the Earth does not mean that the axis is moving in space. In fact, except for the precession and nutation, the rotation axis may be considered to be fixed in space (that is with respect to distant stars). Therefore the statement that the rotation axis moves within the Earth really means that the Earth as a whole moves with respect to the rotation axis while the rotation axis remains fixed in space.

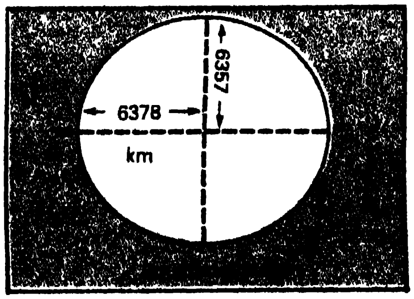


Fig.1. The equatorial bulge and the flattening of the Earth. Primarily due to rotation, the equatorial radius is greater than the polar radius by 21 km. Many of the secondary effects of the rotation of the Earth are due to the presence of the equatorial bulge

The term spin is used interchangeably with rotation; the spin axis and rotation axis are synonymous. A day is the time that the Earth takes to spin around its axis once. Thus an increase in the rate of spin implies a decrease in the length of day (lod for short). Conversely, a decrease in the rate of rotation means that the day is getting longer.

For the benefit of the initiated, the term rotation axis is used here almost synonymously with the "angular momentum vector". Because of the difficulty in visualising an axis that has no immediate physical expression, the former term is preferred.

The Earth rotates from the west to the east; viewed from above the north pole, the rotation is in a counterclockwise sense. It is tautological to state that the Earth rotates once every 24 hours; for, until recently the hour itself was defined on the basis of the period of rotation. The linear velocity of objects at the equator due to rotation is about 1,600 km per hour. Purely under the influence of self-gravitation the shape of the Earth would be a sphere. The principal departure of the shape from perfect sphericity is due to rotation; the Earth is flattened at the poles and bulges out at the equator. The radius of the Earth is 6,378 km at the equator and 6,375 km at the pole (Fig. 1). The size of the "equatorial bulge" depends on the rate of rotation. If the spin rate declined, the bulge would become less pronounced. The equatorial bulge is responsible for other secondary features of rotation, such as precession, nutation and wobble. None of the three motions would exist if the Earth were a true sphere.

In addition, the presence of the bulge lends stability to the rotation axis within the Earth.

The rotation axis of the Earth is not at right angles to the orbital plane of the Earth, around the Sun. Instead, the axis is tilted, and makes an angle of 66.53° to the plane. The complement of the angle, 23.47° is called the "obliquity" (Fig. 2). The existence of the obliquity is the dominant factor in the annual cycle of change in solar insolation in the northern and southern hemispheres, giving rise to the seasons. Normally, aspects of the rotation of the Earth and its orbital motion around the Sun do not invite the interest of governments. But in the 1880's there was a report of "great interest on the part of the Government in Washington" in a plan to reduce the obliquity of the Earth to zero. The project was put forward by the North Polar Practical Association. The Association called for the firing of a heavy projectile to realign the Earth's axis in space! Presumably, the benefit to the United States would have been climatic with the elimination of the seasonal changes in temperature and precipitation. As it turned out, the proponents of the project did not take into account the presence of the equatorial bulge; it is virtually impossible for man to change the obliquity.

The other aspect of rotation that has invited continuing interest from the authorities is the calendar. In 1752, the British government decreed through an act of parliament that the day following 2 September would be 14 September, rather than 3 September. In effect the government had *abolished* the intervening 11 days. Segments of the population did not appreciate the need for the change. Riots ensued because the citizenry thought that the government was cheating them out of 11 days of their lives and the wages for those days.

The cause of the riots went back some 17 centuries, to the Roman Empire. In 45 BC Julius Caesar asked the astronomer Sosigenes of Alexandria to devise an uniform calendar system to replace the confusing Roman system that existed then. The long-term correctness of a calendar depends on an accurate measurement of the number of days in a year. The length of the solar year used by Sosigenes was longer than the true value by 11 minutes and 14 seconds. Although to most of us a small error like that in a year would not matter very much, this small error built up over the centuries until it amounted to 11 days by the time of Pope Gregory XIII in AD 1582. The Pope decreed a new calendar formula that is now known as the Gregorian calendar. The new calendar was not universally accepted right away. It took almost two centuries for the calendar reforms instituted by Pope Gregory to be finally accepted in Britain in 1752. The Gregorian calendar is the one in use today in India and most parts of the world for business and governmental functions.

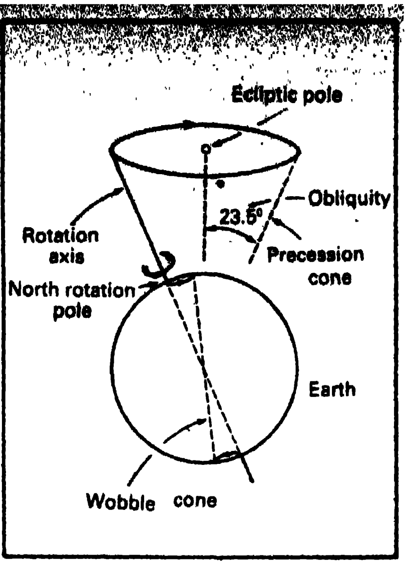


Fig.2. Sketch of the precession and wobble of the Earth's rotation axis. Although shown together in this diagram, the Chandler wobble and the precession are not related. The rotation axis takes 25,800 years to precess once around the cone in space, and 14 months to go around the wobble cone within the Earth. The angle of the wobble cone is small, about 0.3 second of arc

There is a certain disadvantage to the Gregorian calendar in that each year does not necessarily start on the same day of the week and the number of days in the month are randomly distributed among the 12 months. In 1954 the Government of India put forward a proposal to the UNESCO for the worldwide adoption of a "World Calendar", which would have removed the above drawbacks. Unfortunately the UNESCO did not adopt India's proposal and we continue to use the Gregorian calendar.

That the ancient astronomers were able to measure the length of the year quite accurately is demonstrated in the works of Aryabhatta, around AD 476. The length of the year according to his measurements was 365 days 6 hours 12 minutes and 30 seconds. The currently accepted value is 365 days 6 hours 9 minutes and 9.6 seconds. One must remember that Aryabhatta did not have the benefit of either a telescope or an accurate clock, yet his error of measurement amounted to only three minutes.

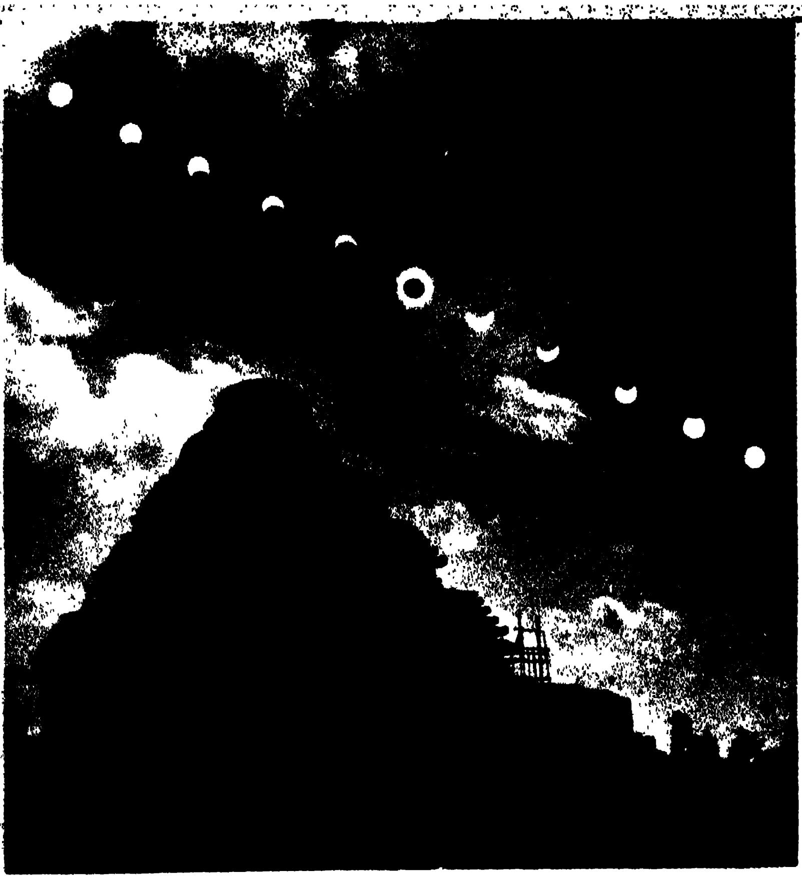
Changes in the length of day

By examining the solar eclipse observations of Claudius Ptolemy (about AD 152) and Abdallah al-Batani (about AD 925) the astronomer Edmund Halley discovered, in 1695, a discrepancy which he attributed to the secular (that is, long term) acceleration of the Moon. If an orbiting satellite moves faster it must move farther away, and vice-versa. Thus the acceleration of Moon implies that it must be gradually spiralling away from the Earth. The explanation of the acceleration was first given by Immanuel Kant in 1754, as being due to the friction between the Moon-induced ocean tides and the solid Earth (Fig. 3). The two consequences of tidal friction are the slowing down of the Earth and the acceleration of the Moon. Because of a better understanding of the physical process in the past few decades, tidal friction is now recognised between other bodies in the solar system, and between close binary stars.

This secular slowing down of the Earth is one of the three broad classes of changes in the spin rate of the Earth. The other two are periodic changes, and irregular changes. The rate of the secular change is about 1.5 milliseconds (ms) increase in the length of day per century. The periodic changes amount to an increase or decrease in lod of about 0.5 ms, with periods of one year (annual) and six months (semi-annual). Irregular changes in lod are due to unpredictable acceleration or deceleration of the Earth and may amount to a 10 ms or so change over a period of weeks.

The long-term astronomical observations that led to the detection of the secular and periodic fluctuations in the spin rate of the Earth is only an indirect method. Since about 1955, atomic clocks have become available with which changes of lod can be monitored directly, much like one would use a stop watch to time the duration of, say, a sports competition. There is a problem with the definition of the unit of time. Originally, the second was defined as 1/86400th part of the day. To measure the changes in the length of the day, a new definition of the second that is independent of the lod became necessary. A second is now defined as the period during which 9,192,631,770 cycles of the hyperfine resonant frequency of the ground state of the cesium 133 atom are counted.

The spin of the Earth may be changed by three distinct physical processes: (1) a redistribution of matter on and within the Earth (or, in the language of physics, a change



Eclipses in classical texts

ALTHOUGH many of the phenomena involving the Earth's rotation are explicable, there is much that is not. Modern observations date from the 1700s. Even though one speaks of secular, annual and semi-annual periodicities in the lod (length of day), there are other periods that are much longer, spanning decades and perhaps even centuries. These can be identified and perhaps explained if reliable figures on lod can be elicited from ancient astronomical observations. The quoted figure of the rate of secular change of lod, 1.5 milliseconds per century, may be confirmed or improved upon by the historical astronomical data. Solar eclipses have been mentioned quite frequently in ancient texts. There have been several attempts to use the historical data, the most recent one is a book by Robert Newton. Considering the antiquity of civilisation in India, it was surprising to find that there is only one reference to an eclipse observed in India. Any additional references to solar eclipses in India will be of some value in the studies of long period changes in lod. To be of use, the description of the eclipse should have a date and place that can be tied in to current geography and calendar. Scholars of the classics in India please note!

in the axial moment of inertia of the Earth), (2) an exchange of rotational energy between the Earth and the Moon (and the Sun), and (3) an exchange of rotational energy between the solid and the fluid parts of the Earth. All three of these processes act in various combinations to produce each of the three types of changes in lod.

Snowfall and rain are seasonal in nature. There is a seasonal shift in mass in the evaporation and precipitation process. There are also seasonal changes in the wind blowing across the surface of the Earth. The energy of the wind is transmitted to the solid part of the Earth and, together with seasonal mass shifts, appears as the changes in the lod with annual and semi-annual periods. Thus the lod can increase or decrease due to wind action and the seasonal mass shifts. The irregular fluctuations in the lod are not yet fully explained, but may also be due to random changes in wind action. Additional discussion on the effects of wind on the Earth's rotation will be found in the section on wobble.

The long-term slowing down of the Earth is most interesting in the sense that it provides clues to the history of the Earth-Moon system. As mentioned before, the Moon is unusually large for a satellite. There are several theories as to how the Earth happened to acquire a large satellite. Among these is the "capture hypothesis". The Moon was originally a planet and happened to come too close to the Earth and was "captured" by the Earth's gravitational field. Since that event, the rate of rotation of the Earth has been affected by the presence of the Moon. The Moon interacts with the rotation of the Earth through ocean tides.

Fig. 3 illustrates the mechanism of tidal friction. The gravitational attraction of the Moon causes the ocean water to form two bulges. The bulges are aligned roughly along the Earth-Moon line on opposite sides of the Earth. The Earth spins much faster than the orbital motion of the Moon. The orbital period of the Moon is 27.3 days. Viewed from space, the Earth is spinning while the bulging ocean water is stationary. To an observer on the Earth, the solid Earth appears to be stationary and it is the tides that ebb and flow. Whatever the view, the net consequence is that the water in the ocean is "rubbing against" the ocean bottom. The resulting loss of energy is maximum along the bottom of shallow seas. As a result of this "tidal friction", the Earth is gradually slowing down, the day is getting longer, and the Moon is accelerating (see the box on page 29).

The tides in the ocean are a visible sign of the response of the fluid part of the Earth to the gravitational attraction of the Moon. Although we cannot see or feel it, the solid Earth also exhibits tidal deformation. The Moon also undergoes periodic deformation due to the gravitational force exerted by the Earth. The deformation is such that there is significant "solid friction" and loss of rotational energy. As a consequence, the Moon has slowed down to a state where the spin period is now equal to the orbital period, about 27.3 days. As far as can be surmised, this is true for all large satellites in the solar system.

Precession and nutation

Because of obliquity, the equatorial bulge is shifted from the orbital plane of the Earth by 23.5 degrees (Fig. 2). The gravitational attraction of the Sun and the Moon acts to displace the rotation axis so that the bulge will coincide with the orbital plane of the Earth. If the Earth was not spinning, the displacement of the rotation axis would take place within a very short time. Instead, the fact of rotation causes the spin axis to "precess" in space, moving on a cone with a period of 25,800 years. As a result, the rotation axis will be pointing at

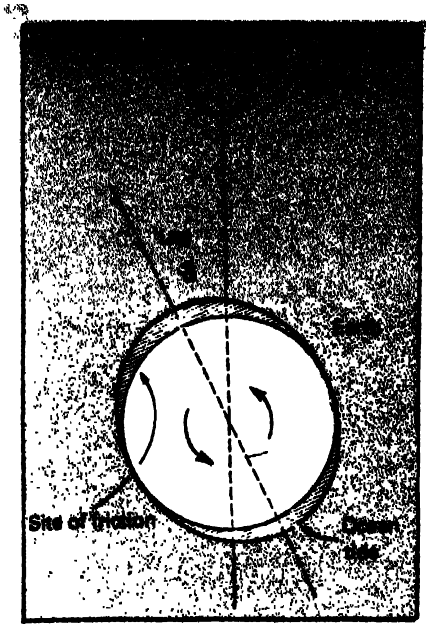


Fig. 3. Tidal bulge and tidal friction. The tidal bulge should point in the direction of the Moon. Because of friction between the ocean and the solid earth, the bulge is carried in the direction of rotation. This lag angle is about 3°. The displaced bulge is responsible for the acceleration of the Moon

different stars as time progresses (Fig. 3). At the present time the "pole star" is the star Polaris. Some 12,000 years hence the rotation axis will be pointing in the direction of the bright star Vega.

In the absence of sufficiently bright stars in the region in between, there will be periods when there will in fact be no pole star. Some 5,000 years ago, the rotation axis was pointing in the direction of the star Thuban.

Periodic variations of the gravitational attraction of the Moon on the equatorial bulge has an effect similar to precession, termed "nutation". Nutation appears as a ripple on the precessional cone. The period of nutation is 18.6 years, much shorter than the precessional period. The amplitude of nutation is about 9.8" of arc, also much smaller than the 23.5° precession.

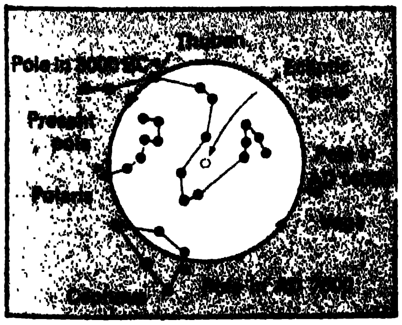


Fig. 4. The Pole Star. With precessional motion, the star directly overhead at the north pole changes with the centuries. About 5000 years ago the pole star was Thuban. The present pole star, Polaris, will not be so in a few thousand years. Around AD 14000 the bright star Vega will become the pole star

Precession exists because of the obliquity of the rotation axis. The obliquity itself is oscillatory, currently changing at the rate of 47" per century, with an estimated period of about 40,000 years. This periodicity of the obliquity is caused by the gravitational attraction of the other planets on the orbital plane of the Earth.

Experiments with spinning eggs

We can obtain a good physical insight into the motion of the rotation axis within the Earth with some simple experiments with spinning eggs. The spinning boiled egg illustrates the wobble. The spinning raw egg illustrates the spin of the solid and fluid parts of the Earth.

The first experiment involves spinning a hard boiled egg around its long axis on a smooth kitchen table. As shown in Fig. 5, the egg executes a series of complicated motions to end up spinning around a short transverse axis. We find that however hard we try, the egg always ends up spinning around the short axis. Even without any knowledge of physics we can state that for some reason the egg prefers to spin around its short axis. In the language of physics, every free spinning body has at least one axis around which the moment of inertia is maximum. This axis is referred to as the "axis of figure". In fact if the body is rotated around an axis that is not the figure axis, the rotation axis will slowly spiral towards the figure axis. Ultimately the two axes will become coincident.

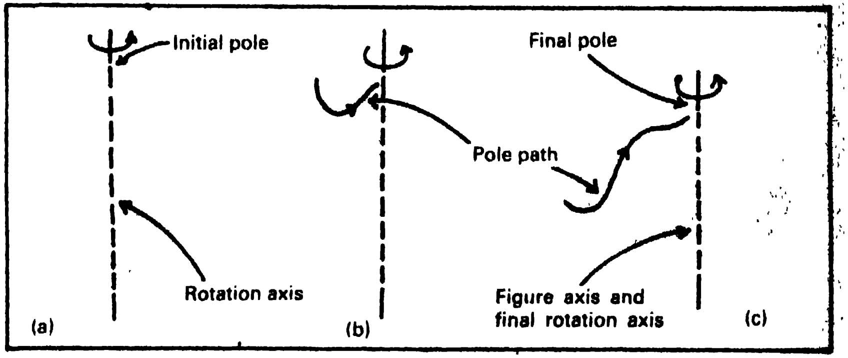


Fig.5. Rotation of a boiled egg. If a boiled egg is set spinning on a smooth table with its long axis vertical (a), the egg soon executes motions (b) such that it spins round its short axis (c). The spin axis continues to point upwards. The egg moves with respect to the spin axis. An observer on the egg will observe the rotation pole migrate along some complicated path from the tip at the narrow end to a point in the middle

Fig. 5 also shows that we can describe the process by which the egg changed from the initial longitudinal axis to the short transverse axis of rotation as a motion of the rotation pole along the surface of the egg. The rotation pole passes from the tip of the narrow end of the egg to a point in the middle of the egg. Looking from outside the egg, however, we see that the egg has actually changed its orientation during the process of changing from a longitudinal rotation axis to a transverse rotation axis. An observer on the egg will note the change of the orientation of the egg by charting the change of objects directly overhead. For example, an observer looking overhead at the initial rotation pole at the narrow end will see the ceiling of the room. With the motion of the rotation pole along the surface of the egg, the observer at the narrow tip will see more of the walls of the room and less of the ceiling.

For the Earth, as a result of pole motion, the position of the stars overhead at any place will shift slightly. Measurements of the shifts in star position and analysis of periodicity led to the detection and confirmation of the wobble of the Earth. Two views of the process by which the Earth expresses the tendency to rotate around the axis of figure describe the same phenomenon. The Earth-fixed view shows a motion of the rotation axis within the Earth describing a cone. The space-fixed view shows a fixed rotation axis, with the Earth changing its orientation in space. Notice that with our egg the rotation axis keeps pointing vertically while the egg readjusts itself so as to be able to rotate around the stable axis.

Our second experiment involves a raw egg. In attempting to make it spin, it is noticed that the unboiled egg is more difficult to spin than the boiled egg. Once it is spinning, it can be stopped by touching momentarily with a finger. As soon as the finger is withdrawn, however, the egg starts moving again. If the same experiment is repeated with the boiled egg, It will be found that the boiled egg does not move after being stopped. The reason for the strange behaviour of the raw egg is due to the fact that the outer solid shell is attached loosely to the inner liquid part of the egg. When we attempt to set the egg spinning, the liquid part does not immediately follow suit. That accounts for the difficulty in setting the raw egg spinning initially. When the shell of the spinning raw egg is touched momentarily the shell is brought to rest; but the liquid interior is still moving. If the finger is withdrawn from the shell before the internal liquid has had time to come to rest the outer shell will be made to move again.

On a rough scale the Earth is 2,900 km of the crust and mantle (solid), followed by about 2,300 km of liquid core, and finally about another 1,200 km of solid inner core. Above us extends the atmosphere, and of course we must not forget the oceans (Fig. 6). Thus we are looking at three main fluid parts of the Earth, and two solid parts. The motions of such a structure are not simple. Because the two solid parts and the three fluid parts can move independent of each other, several complicated and interesting features of rotation arise.

The Chandler wobble and other wobbles

Any periodic motion of the spin axis within the Earth is termed a wobble (Fig. 2); a permanent shift of the axis is called "secular polar shift" or "polar motion". The amplitude of the wobble is given either as the angle of the cone described by the rotation axis within the Earth or as the radius (in feet) of the cross-section of the cone in the polar region. Secular polar shift will occur if there is a continuing and permanent rearrangement of the matter on and within the Earth, such as through sedimentation (matter is carried from the continents and deposited in the ocean), mountain-building, large-scale uplift or subsidence of land masses.

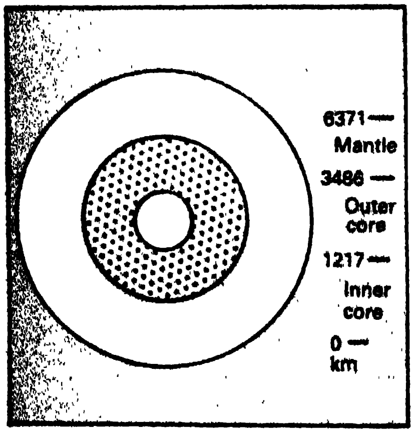


Fig. 6. The structure of the Earth. The mantle and inner core are solid, while the outer core is a fluid. In this sketch, the thin crust is considered a part of the mantle. The oceans and the atmosphere are not shown. The Earth's motions are complex because the different parts can move relative to each other

The mean position of the north rotation pole during the five-year period 1900 to 1905 is accepted as a geographical reference point. In the intervening 70 years or so the mean rotation pole has shifted some 20′ towards eastern Canada. This, however, is not a true estimate of the secular polar shift. In the past decade a major development in the earth sciences has been the "plate tectonics hypothesis". The surface of the Earth is composed of several "plates", about 100 km thick, which move relative to each other. The measured secular polar shift cannot distinguish between the effect of true mass redistribution within the Earth and that due to the motion of the measuring instruments, carried along on the plates.

Among the wobbles of different periods the Chandler wobble is the most noteworthy, which we discuss in detail. The others are, the "nearly diurnal wobble", the annual wobble and the semi-annual wobble. The nearly diurnal wobble has a period just a few minutes short of a day and is due to the motions of the liquid core. The estimated amplitude of this wobble is about 2′, just at the borderline of detectability at the present. Its reality has not yet been confirmed. The amplitudes of the annual and the semi-annual wobbles are 9′ and 1′ respectively. They are caused by the same processes that cause the annual and seasonal changes in the lod. The annual mass shifts change the position of the figure axis within the Earth, and excite the two wobbles.

When Leonhard Euler worked out the equations describing the complex motions of a rotating body in 1765, he suspected that the axis of rotation of the Earth may not be coincident with the axis of figure. As a result the axis of rotation must be moving within the Earth. He expected the motion of the axis to be periodic, with a period of about 10 months. For some 120 years after Euler, many astronomers and physicists looked for evidence of a wobble of the Earth with a 10-month period, all unsuccessfully. Finally Seth Carlo Chandler, in Boston, Massachusetts, announced the discovery of the wobble in 1891, but the period was 14 months instead of the 10 months predicted by Euler. The difference was due to the fact that Euler had not taken into account the elastic deformation of the Earth. The amplitude of the Chandler wobble is about 4.25 metres, at the poles, or 0.14 second of arc.

After the identification of the wobble the natural question was why does the wobble exist? We have seen that in the case of the egg, the rotation axis tends to move fairly quickly within the egg in order to coincide with the stable axis of figure. If for some reason the rotation axis of the Earth was not initially coincident with the axis of figure, then within about a 1,000 years or so the rotation axis should have moved in to coincidence with the axis of figure. The conclusion is inescapable that some process is keeping the axis of rotation and the axis of figure apart, in spite of the constant tendency of the axis of rotation to spiral towards coincidence with the axis of figure. The problem is called "excitation of the Chandler wobble" and is currently the topic of active research by geophysicists.

There are two physical processes that can excite the Chandler wobble: (1) a redistribution of mass on and within the Earth that shifts the axis of figure; and (2) a realignment of the fluid parts of the Earth with respect to the mantle so that the axis of rotation is shifted internally. Large scale motion of the winds can make the Earth spin faster or slower, or spin with slightly shifted rotation axis. What we cannot calculate accurately is by how much the winds can affect the spin of the Earth. The maximum effect of the wind must be by pressing against the rough part of the Earth's surface, as in the Himalayas. Yet it is in those rough parts that we do not have close and precise measurements of wind velocity. Recall that the wind motion affects the spin rate of the Earth, changing the length of the day. Here the hypothesis is that winds shift the spin axis of the Earth, thus exciting the wobble.

The mass of the core (the inner and outer cores taken together) is almost half the total mass of the Earth. The flattening of the core and the bulging out in the equatorial region is less than that of the whole Earth. If the core were an independent body, all its motions would be of different amplitudes and periods from that of the whole Earth. However, the core and the mantle are attached together, and have a combined motion. Because the outer core is a fluid, there is some question as to how tightly (or loosely) the core and mantle are coupled. In addition the actual physical properties of the bottom of the mantle and the top of the outer core that determine the coupling are not known (this is called the core-mantle coupling problem). Is the bottom of the mantle rough? If so, the roughness can be a contributing factor in the coupling. We know that the liquid core can conduct electricity, as possibly can the bottom part of the mantle. Depending on the strength of the local magnetic fields, the liquid core may be lightly or tightly attached to the mantle. Because the core is so massive, and has a tendency to move independently of the mantle, any change in coupling, or any change in the motions of the core can appear as a change in the spin rate and/or a shift of the spin axis of the Earth, thus exciting the wobble.

Finally we are left with any process that can shift the axis of figure of the Earth. Until about 15 years ago there was no process that was considered sufficiently large to be able to do so. It has been proposed that large earthquakes rearrange the mass worldwide on a sufficiently large scale to be able to shift the figure axis and keep the wobble alive. However, the idea has not been proven conclusively yet.

Physical effects

Most of the physical effects of rotation are mentioned in high school and college textbooks. We will skim over these effects very briefly. Because of the rotation of the Earth, all experiments and observations made on the Earth is on a rotating platform. Every first year physics student knows Newton's laws by heart. But these laws are valid only in an inertial reference frame, that is, a reference frame that is fixed in space. The closest one can come to such an ideal reference frame is to define a coordinate system with reference to distant stars. Because the Earth is a non-inertial platform, phenomena observed on and from the Earth are subject to the influence of rotation. Long range guns and missiles have to be corrected for the rotation during firing. Airplane travellers flying directly west notice the prolonged sunsets. The rotation affects the prevailing wind directions and the flow of ocean currents. In fact all motion is affected through the Coriolis force. In one aspect or another the fact of rotation touches the lives of all plants or animals. Many animals exhibit an internal circadian clock, developed after millions of years of evolution in a diurnally varying environment.

The magnetic field of the Earth is weak; but it provides a shield against cosmic rays. The source of the magnetic field is not yet known. But it is suspected that the field is due to large loops of electric current within the Earth. The current is generated by a "self-exciting dynamo". Because of the close association between the magnetic axis and the rotation axis there is a strong possibility that the dynamo draws its energy from the Earth's rotation.

The Earth-Moon system

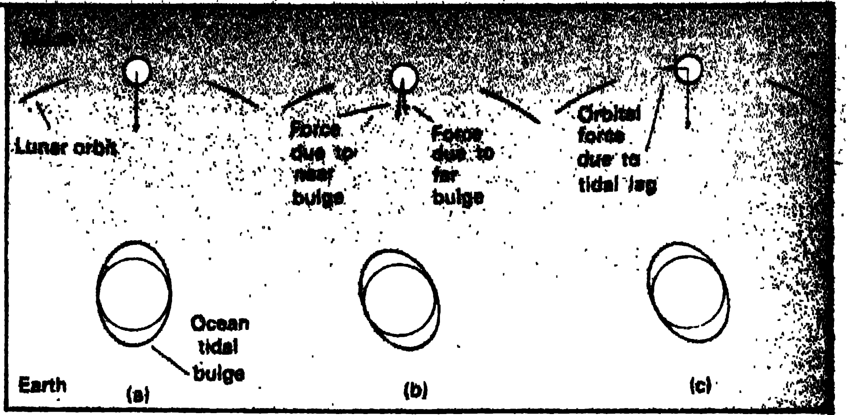
We have concentrated mainly on one aspect of the gravitational interaction of the Earth and the Moon, that of tidal friction and the consequent slowing down of the Earth. If one accepts the capture hypothesis of the Moon, particularly the one in which the Moon was originally in a retrograde orbit around the Earth, then some additional interesting and spectacular effects must have occurred in geological times.

Friction implies generation and dissipation of heat. The "braking" of the Earth due to tidal friction must

The Earth-Moon distance is increasing

THE acceleration of the Moon is a direct consequence of tidal friction. If there was no tidal friction, one tidal bulge would be exactly in the direction of the Moon, and the other would be at the antipode. The gravitational attraction due to the bulges would be along the Earth-Moon line and there would not be any component of the force causing the Moon to accelerate (Fig. a). Because of friction between the solid earth and the ocean water, the bulges of water are displaced slightly, by some 3 to 5 degrees, in the direction of rotation of the Earth (Fig. 3; Fig. b). To an observer on the Earth this "tidal lag" would mean that the peak of the lunar tide will not be at the time at which the Moon crosses the meridian but some 10 to 20 minutes later.

The tidal lag makes the two tidal bulges asymmetric with respect to the Moon. The nearer bulge exerts a gravitational force on the Moon, as does the farther bulge (Fig. b). However, because of the difference of the distances of the two bulges from the Moon, the attraction of the nearer bulge is stronger than that due to the far one. Also, the two attracting forces are in different directions. A simple resolution of the two forces into components parallel and normal to the Moon's orbit, and adding the components together, show that the resultant is a net force in the sense of the Moon's own orbital motion (Fig. c). As a result of this force the Moon is accelerating ever so slightly.



The role of tidal friction in the acceleration of the Moon: (a) If there was no tidal friction the oceanic tidal bulges would be aligned with the Moon. The gravitational attraction of the bulges on the Moon would be directed along the Earth-Moon line. There would be no net force on the Moon in the direction of the orbit to cause it to accelerate. (b) With tidal friction the two bulges are no longer aligned with the Moon, but displaced by some 3 to 5 degrees. The attraction of the bulges on the Moon are unequal and in different directions. The nearer bulge exerts a greater force on the Moon. (c) Combination of the attractive forces shows a resultant force in the sense of the Moon's orbit. The Moon is gradually moving faster, and away from the Earth as a result of this force

The distance of the Moon from the Earth is determined by the orbital velocity of the Moon, as well as the strength of the gravitational 'pull' of the Earth on the Moon. The weaker the pull and/or higher the orbital velocity, the larger is the orbit. The acceleration of the Moon thus implies that the Earth-Moon distance is increasing. The orbit of the Moon around the Earth is not a closed ellipse but instead is a gradually widening elliptical spiral. The Earth-Moon distance, which is about 384,000 km at present, is increasing at the rate of 3 cm per year.

mean that heat generated is dissipated somewhere within the Earth. As the Earth slowed down, it also must have heated up. Because the original speed of rotation of the Earth is not known, one can only guess as to the amount of heating that has occurred. It is possible that the capture of the Moon has had some role in the formation and growth of the liquid outer core.

Numerous orbital parameters of the Earth and the Moon are affected by the tidal-gravitational interaction of the two bodies over a very long period of time. The eccentricity of the orbit, the orbital period and the spin period of the Moon have been affected by the Earth. Similarly, the Moon has influenced the obliquity and the Earth-Moon distance, in addition to the length of the day.

The complete scenario is fascinating. Initially the Earth was rotating with a period of 2.6 hours, a very short day. The Moon was captured in a retrograde orbit, with an orbital inclination of about 50° and an orbital period of 50 Earth days. Due to tidal friction the Moon very gradually spiralled in towards the Earth until about 1.2 billion years ago, when rapid and spectacular changes took place. Within a short period of time the Moon approached to within 18,000 km of the Earth, as compared to the present distance of 384,400 km. The orbital inclination increased to 90°, a circumpolar orbit, with a period of 5 hours, down from 50 days. At the same time the obliquity of the Earth decreased to 10°. Unfortunately man had not evolved then, otherwise the sight of a gigantic Moon moving in a polar orbit every 5 hours would have been magnificent and unforgettable.

From about 1.2 billion years there have been slow changes leading to the present state. The obliquity increased to its present value of 23.5°. The lod increased to 24 hours from the original 2.6 hours. The Moon's orbital inclination decreased from 90° to its present value, and the orbital period increased to the present value of about 27 days. The Moon's spin rate changed until it became locked on to the Earth.

In conclusion, we have seen that aspects of the rotation of the Earth provide a rich field for research and speculation involving current and past geodynamic processes. In this article we have only briefly touched upon the more interesting aspects. With the current level of interest, there is a promise of continued development in this subdiscipline of geophysics.

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ANGULAR MOMENTUM IN THE SOLAR SYSTEM

D. ter Haar

Why does the Sun spin so slowly?

OUR solar system consists of the Sun, the nine planets (Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune and Pluto), various moons or satellites of the planets, asteroids, and comets. The system shows certain regularities which may be the result of the way it was formed. Some of them may be also the result of gravitational interactions between the bodies. There is at the moment no general agreement on how the solar system was formed, or the way the planets and their satellites were produced. These are still being vigorously debated. However, the fact that the satellite systems of Jupiter, Saturn and Uranus seem to be miniature copies of the solar system, many think, provides an important clue. What should also help in sorting out the various theories is the additional information the recent fly-past of Jupiter and Saturn by the two Voyager spacecraft is giving about these planets and their satellites. But in the present article, we are concerned merely with problems of the angular momentum in the solar system.

What is the distribution of angular momentum in the solar system? We shall discuss only two aspects about which a lot of relevant data are presented in Tables 1 and 2. We have not listed Pluto in these tables, as it clearly does not belong to the "regular" system of planets.

Table 1 is concerned with the total angular momentum of the system. As the orbits of all the planets are more or less in the same plane, their angular momentum vectors are also practically in the same direction, so that all we need is to merely list the magnitude of these vectors. This is done in the last column of Table 1. Comparing the data in the second and the last columns of this table, we note that while the Sun accounts for 99.9 per cent of the total mass of the solar system, only 0.2 per cent of the total angular momentum is vested in the Sun. (That the Sun rotates is easily seen by tracking sunspots, etc: see Fig. 1).

Table 2 lists the angular moments of the planets and the Sun around their own axes. While calculating their moments of inertia, we have made the simplifying assumption that they are spheres of uniform density. The fact that this makes their moments of inertia rather large is, however, irrelevant to our present discussion. Now, although the intrinsic angular moments of the various bodies in the solar system vary very widely, an amazing feature emerges from the second table's last but one column: the rotational periods of the six outer planets are the same within a factor of about two. Significantly, the rotational periods of most of the asteroids also lie in the same range.

Let us now turn our attention to the distribution of angular momentum. The angular momentum of the planets in their orbits is completely determined by the fact that in the gravitational field of the Sun they move in Keplerian orbits. Bodies in Keplerian orbits observe the following laws: each orbit is an ellipse with the Sun at one focus; equal areas are swept out in equal times; and the square of the period is proportional to the cube of the distance from the Sun.

The Sun itself rotates very slowly. But why does the Sun do so? For this, we must look into the problem of the Sun's formation. It seems that the Sun was formed with a very large intrinsic angular momentum, possibly close to the value corresponding to rotational instability, that is, the value of angular momentum large enough to break up the star.

Rotational instability occurs when the centrifugal force at a celestial body's equator equals its gravitational force. For the Sun with its present mass and radius, this would correspond to a rotational velocity of the order of 400 kilometres per second This is, of course, the same as the Kepler velocity at the Sun's surface. Such a high rotational velocity would not only restore to the Sun the lion's share of the angular momentum in the system, but also lead to a rotational period of the same order as that of the Jupiter. As this also means that the Sun in the early stages of its life was rotating faster, one must find a mechanism for the Sun —and for that matter for any star— which helped it shed a large amount of angular momentum during its formation. We shall consider these two stages of the evolution of the Sun's angular momentum separately.

One theory of the origin of the solar system, which goes back to Laplace and was recently resurrected by A. J. R. Prentice, assumes that the primeval Sun, while contracting regularly, shed rings of matter which contained the excess angular momentum. This would, of course, lead to a Sun with a rotational velocity of the order of 400 kilometres per second and, at the same time, to rings of matter from which the planets could form. Earlier, the same author had suggested another mechanism for the losing of the excess angular momentum. But, before we go further, let us look into the theory of star formation in some more detail.

Genesis of the rotating star

Let us consider a scenario for the formation of the Sun that follows the Reddish-Wickramasinghe collapsing-dust-cloud theory. An interstellar gas cloud with an average density of about 20 atoms per cubic centimetre and a total mass of about 10,000 solar masses will collapse and break up into fragments of about one solar mass each when it has reached a density of about 10,000 atoms per cubic centimetre. At that stage it will rotate uniformly with an angular velocity corresponding to a rotational velocity of about 60 metres per second at the edge of the cloud, which has a radius of about one-third of a light year. As this corresponds to an angular momentum of the protostar which is about 1000 times larger than the one corresponding to a rotational velocity of 400 kilometres per second, it must shed about 99.9 per cent of this angular momentum in this first stage. Practically all atoms, except the helium atoms, in this fragment, will be condensed into dust grains. The helium will be partly neutral and partly ionised. The helium ions and the electrons, moreover, will be tightly tied to the interstellar magnetic field which extends through the fragment and beyond.

Let us now consider the dynamics of this system: the grains, subject to gravitational forces, tend to make the grain component collapse, while a viscous drag force due to the neutral component (because of collisions) will oppose the collapse. The neutral component suffers a drag due to the grains as well as the ionised component, while the ionised component is subject to the drag by the neutral component as well as a force due to the magnetic field (Fig. 2). In the first stage of the collapse, the neutral component stays put. This is because the force due to the ionised component is much larger than that due to the grains. However, once the grain component has collapsed so that the drag force due to it on the neutral component exceeds that due to the ionised component, the grain and neutral components will collapse together This will leave the ionised component behind, because it is tied to the magnetic field which in turn is tied to the magnetic field outside the proto-Sun. Finally, the collapse has proceeded so far that the drag on the ionised component due to other components exceeds the magnetic force and then everything — including the magnetic field — will be swept towards the centre.

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Fig. 1. The great sunspot group of May 1951, designated as Kodaikanal No. 9620 (KKL 9620), during its passage across the solar disc from 10 to 21 May. Sunspots observed regularly for a few days show that the Sun rotates once in 25 days

Table 1

Planet	Mass (M; in 10^{24}kg)	Mean distance from Sun (d; in 10^{10}m)	Mean velocity in orbit (v; in km/s)	Angular momentum with respect to Sun's centre ($L_1 = Mvd$; in 10^{37}kg m^2/s)
Mercury	0.3	6	50	90
Venus	5	11	35	2×10^3
Earth	6	15	30	3×10^3
Mars	0.6	23	24	4×10^2
Jupiter	2×10^3	78	13	2×10^6
Saturn	600	140	10	8×10^5
Uranus	90	290	7	2×10^5
Neptune	100	450	5	3×10^5
Sun	2×10^6	(radius = 0.07)	(mean velocity at equator = 2)	($L_1 = L_2 = 6\times10^4$)

In the latter stages of the collapse, no angular momentum will be lost.

But, in the first stage, the drag on the grains due to the neutral component will transfer angular momentum from the grain component to the neutral component and then via the interaction between the neutral and the ionised components and via the magnetic field to the outside. Quantitative estimates of the total amount of angular momentum so lost indicate that, indeed, about 99.9 per cent of the original angular momentum can be shed in this way. Thus, at the end of this collapse process, we are left with a central mass rotating with a rotational velocity of the order of 400 kilometres per second. Though, at this stage, the Sun will still be surrounded by a gaseous envelope from which, later, the planets may be formed.

Let us now see whether it is possible to devise a process by which the rotational velocity of the Sun could have been reduced from an initial value of the order of 400 kilometres per second to its present value of about 2 kilometres per second. We must thus once again find a way to lose about 99.5 per cent of the angular momentum. Of course, as soon as there is a central condensation, which means that the proto-Sun has begun to look like the Sun as it is now, the angular velocity in the envelope will be governed mainly by the gravitational field of the Sun. The angular velocity in the envelope will decrease as one moves away from the centre (compare the last but one column in Table 1), and viscosity will lead to a transport of angular momentum outwards. However, to find the magnitude of this transport one must take into account the fact that it will be larger than what one would calculate using the viscocity coefficient of the gas. This is because the envelope will be turbulent leading to an increased effective viscosity.

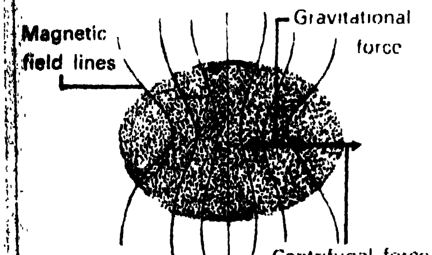

Fig. 2. A star in formation. The whirling cloud condenses due to gravitational attraction among its constitutents The lines of magnetic force threading the cloud are compressed with it leading to an increase in magnetic field strength All matter in the cloud is subject to a gravitational force which acts inwards, towards the centre It is also subject to forces which act outwards—force due to collision between the matter and the centrifugal force due to rotation. Only ionised matter is acted on by the magnetic field

Table 2

Planet	Mass	Radius	Moment of inertia	Axial rotational period	Angular momentum around its own axis
	(M; in 10^{24} kg)	(R; in 10^6m)	($I = \frac{2}{5}MR^2$; in 10^{38}kg m^2)	(P; in hours)	($L_2 = 2\pi I/P$; in 10^{37}kg m^2 s^{-1})
Mercury	0.3	0.2	4×10^{-3}	1400	5×10^{-8}
Venus	5	0.6	0.4	6000	10^{-6}
Earth	6	0.6	0.5	24	4×10^{-4}
Mars	0.6	0.3	0.01	25	10^{-5}
Jupiter	2×10^3	7	2×10^4	10	35
Saturn	600	6	4×10^3	10	7
Uranus	90	3	200	21	0.2
Neptune	100	1.3	35	13	0.05
Sun	$2\cdot10^6$	70	2×10^9	600	6×10^4

This transport of angular momentum will operate as long as the envelope exists. The viscosity itself leads to dissipation and the increased viscocity will tend to break up the envelope sooner, which, in fact, leads to a smaller total loss of angular momentum. In fact, when one puts numerical values into the equations, it turns out that the viscous drag can only carry away a tiny fraction—probably not more than one-millionth of the original angular momentum. This we estimate to be, in the units of Tables 1 and 2, of the order of 10, corresponding to an equatorial velocity of the order of 400 kilometres per second. Thus viscous drag cannot account for the observed slowing down.

Another possibility why the Sun lost most of its original angular momentum is that its (rotating) magnetic moment interacting with the surrounding ionised gas transferréd some of its angular momentum to the latter. This process is analogous to the slowing down, due to eddy currents, of a sheet of iron falling through the gap of an electromagnet. As early-type stars are so much younger than the late-type stars, this mechanism would have worked during a much shorter period for O-, B-, and A-stars. This might explain the fact that these bright young stars are still on the whole rotating rapidly, while the older late-type stars like our Sun are on the whole rotating slowly. A careful study shows further that this electromagnetic mechanism may be sufficiently efficient to have produced a slowly rotating Sun.

In summary, then, our Sun may have reached its present state of slow rotation in two ways. The proto-Sun may have lost a very large fraction of the angular momentum through a transfer mechanism using the tight coupling between ions and the interstellar magnetic field. And the remainder of the excess angular momentum was perhaps shed by producing eddy currents in its surroundings — again a magnetic effect.

To conclude this discussion of the angular momentum distribution in the solar system, I want to return briefly to the amazing fact that the rotational periods of the six outer planets, as well as those of most asteroids, all lie in the same range, while their masses range from about 10^{15} kg for small asteroids to 2×10^{27} kg for Jupiter. Alfven and Arrhenius have shown that one can explain this uniformity of rotational periods by considering how an initially small nucleus will grow by accretion. What happens in such a process is that the grains hitting the proto-body hit it on an average with a velocity corresponding to an orbit which just grazes the surface of the proto-body. Grains which have a larger velocity when closest to the proto-body will miss it — there is, in fact, a selection of grains such that only those with a relatively small angular momentum with respect to the proto-body will strike it. As the average angular velocity of the grains striking the proto-body depends solely on the density of the proto-body, and as all the bodies we are considering have roughly the same density, we may expect roughly the same angular velocities, that is, the same rotational period for these bodies.

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Fig. 1. This photograph of the periodic Comet Encke shows the central condensation, possibly indicating the nucleus of the comet. The picture was taken on 10 October 1980

THE computed orbits in many comets seem to differ from the observed positions every time they return to the solar system. Take Comet Encke, discovered in 1786, with a period of 3.3 years. It surprised cometary observers by returning after each revolution about 2½ hours too soon, a difference outside the possible errors of measurement or calculation. The fact was noticed by Encke himself as far back as 1820.

The orbit of a comet can be calculated by methods based on Newton's laws of gravitation. How good the determined orbit is will depend upon the number of observations available for the comet. Since short-period comets can be observed more often, the orbits of these can be determined accurately. As a comet approaches the inner part of the solar system, its motion is influenced strongly by the planets. The perturbations change the trajectory of a comet and could be taken into account using high-speed computers. Earlier workers introduced the idea of a resisting medium to explain the discrepancy between the calculated and observed arrival times of comets. However, the results of many comets demonstrated that the resisting-medium hypothesis is certainly not correct. Studies have shown that roughly half the comets are accelerated and half retarded, which implied an additional force not included in the calculations, one which seemed non-gravitational in character. The rotating icy-nucleus model of the comet provides a simple explanation for this non-gravitational effect.

The nucleus of a comet is estimated to be about a kilometre across. This small size makes it hard for us to observe. To understand the nucleus, it is essential to know some relevant feature of a comet.

A comet revolves around the Sun in various orbits, generally ellipses. The orbital period of comets varies from a few years to a few million years. When it is far off from the Sun, it looks as a small fuzzy patch of light. Its brightness changes markedly as it approaches the Sun. This is due to the cloud of gas and dust, called the coma. At the centre of the coma is a star-like point source of light called the "nucleus" of the comet. It cannot usually be seen, except when it is very far away from the Sun, as it will be masked by the surrounding nebulocity (Fig. 1). The ion and the dust tails (Fig. 2) of the comet develop as it approaches the Sun. The comet is essentially seen through the solar radiation scattered by the dust particles and by re-emission of the solar radiation absorbed by the gaseous material.

The nucleus must be a permanent feature of a comet and most of the observed phenomena are directly or indirectly connected with the nucleus. The characteristics of the nucleus have to be deduced from indirect evidence based on observations of the coma and tail. At present, the most successful model for the nucleus is the "icy-conglomerate" model proposed in the 1950s by Fred Whipple, the well-known expert on comets. In his model, the nucleus is a compact body consisting of ice, volatile materials formed out of hydrogen, carbon, nitrogen and oxygen, and meteoritic material.

As seen in Fig. 3, when solar radiation falls on the nucleus, it quickly evaporates the material from the surface. The outgassing occurs on the sunlit side of the nucleus which generates a jet action, a force pushing the comet away from the Sun (Fig. 3a). If the nucleus is rotating (spinning), there will then be a time delay between the heating and the ejection of the gas from any point on the surface. If the rotation is in the same direction as its motion around the Sun, the delayed jet action will have a forward component which will increase the comet's orbital period (Fig. 3b). As a result, it will show up later than predicted. On the other hand, if the nucleus rotates opposite to its motion around the Sun (Fig. 3c), the jet action will have a backward component. This will reduce the period of the comet. It will therefore show up earlier than predicted. If the axes of rotation of the nucleus is randomly distributed, then one should expect half of them to be accelerated and half to be retarded. This seems to be consistent with the observations.

The next step is to examine the variation of the rate of sublimation of

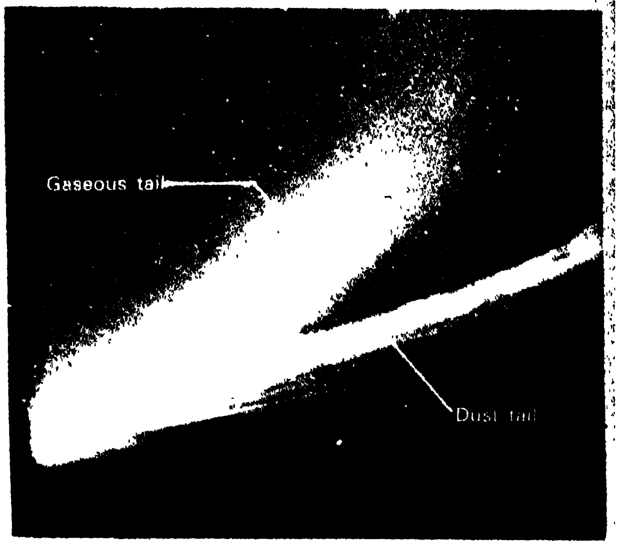

Fig.2. Photograph of Comet Mrkos (1957) clearly shows two tails—a dust tail and a gaseous tail. Cometary tails are produced by matter evaporating from the surface of a cometary nucleus as it nears the Sun

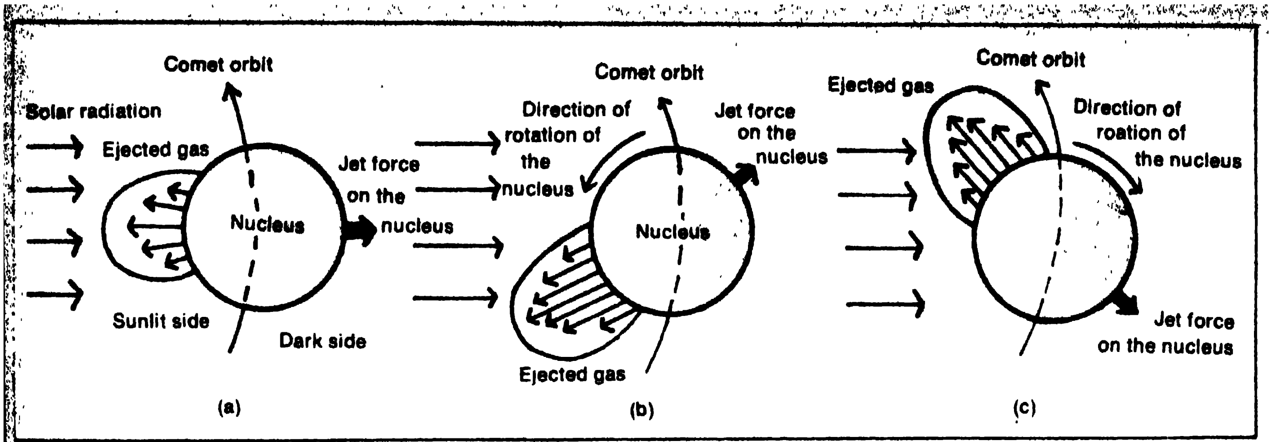

Fig.3. The result of outgassing on a cometary nuclei, when (a) the nucleus does not rotate, (b) the nucleus rotates along the direction of motion around the Sun. The jet force is also along the direction of motion which increases the period of the comet, and (c) the nucleus rotates in the opposite direction to the direction of motion around the Sun. The jet force is now in the opposite direction to its motion resulting in a decrease in the period of the comet

possible ice in comets with distance. From a detailed work, it is now possible to make a meaningful comparison of the non-gravitational parameters for different comets as they represent the relative mass loss rates. However, there was still a problem in that one required the outgassing to be much higher than what was known at that time. Otherwise the jet force was not enough to exert an adequate force on the comet. This dilemma was resolved when the Orbiting Astronomical Observatory detected for the first time in 1970 a large cloud of hydrogen gas from Comet Bennett. The radiation from the molecule OH was also detected. In addition to H and OH being very abundant, the ratio of the two indicated that they arise mainly from the dissociation of the water molecules. Later on, the molecules H_2O and H_2O^+ were also detected. All these give strong evidence that water is the major constituent of comets, which in turn, supports the rotating icy-conglomerate model for the nucleus.

Every time the comet returns, newer material on the surface of the nucleus is exposed to the solar radiation because of the mass loss process. The rate of outgassing of the molecules from the nucleus is a complex function depending upon numerous factors like, for instance, surface temperature, nature of volatiles, structure of the nucleus like whether it is porous or there are cracks in it, temperature induced stresses, etc.

There are certain other observations, seen photographically and visually, on comets which have been interpreted in terms of the rotating nuclei model, to get an estimate of the rotational period and the direction of the spin axis of the nucleus. (1) Many comets seem to show a broad fan-shaped coma coming out of the central condensation and in the general direction of the Sun. The width appears to change from comet to comet and with time. They have been interpreted in terms of anisotropy (non-uniformity) in the outgassing. The sense of rotation obtained from these studies is shown to be consistent with the results based on the analysis of the non-gravitational force affecting their orbital motions. There is also a tendency for the spin axis to turn towards the Sun near perihelion—the point at which the comet comes closest to the Sun. (2) The photographic observations of many comets indicate successive expanding halos with velocities of about 0.5 km per second. Whipple has interpreted these observations as a repetitive ejection of material and gives a method for estimating the rotational period of the nucleus. The period for Comet Donati is found to be about 4 hours 40 minutes and that of comet Encke, 6 hours 33 minutes. In general, the rotation period is found to be between 4 and 15 hours.

The non-gravitational parameters indicate that about 0.2 per cent of the material is lost from each comet in one revolution. A study of the variation of the transverse component with time is more significant as it will give a sort of life history of the nature of the nucleus. A thorough analysis of the comet Encke, which has been observed for the last two centuries, has been carried out recently by Whipple and his co-workers on the basis of an oblate spheroid rotating about its minor axis. They are able to explain most of the observed properties of this comet over this long time period. The results also show that the spin axis precesses with time.

Therefore the outgassing from a rotating icy nucleus model can explain not only many of the observed features of a comet but also secular (long-term) effects in the orbital mean motion of comets.

The very small size of a cometary nucleus makes it almost impossible to observe many of the fundamental characteristics from the ground or even from Earth-orbiting satellites. However, the nucleus could be seen with a space probe which flies past it a few hundred kilometres away. Such probes are being planned for Comet Halley which has a period of 76 years and is expected to be back in 1986. The European Space Agency is going ahead with a project. Other countries, including India, are also making their own plans. Hopefully, with these closest approach studies, one will be able to answer many of the unsolved problems, including the spin of the nucleus.

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Recommends reading: **1.** F. L. Whipple, *Astrophysical Journal*, **3**, 375 (1950); **2.** B. G. Marsden, "Comets", *Annual Review* of *Astronomy and Astrophysics*, **12**, 1 (1974); **3.** B. G Marsden, "Non-Gravitational Forces in Comets", *The Study of Comets*, IAU colloquium No. 25, NASA SP-393, 465, (1976); **4.** F. L.. Whipple, and Z. Sekanina, "Comet Encke—precession of the spin axis, non-gravitational motion and sublimation", *Astronomical Journal*, **84**, 1894 (1979)

ROUND-UP OF RESEARCH

Mutants of measles virus

MEASLES is an acute, highly infectious viral disease and is of worldwide endemicity. The causative agent of measles, a paramyxovirus, has a single, double-stranded RNA genome, whereas the closely related influenza viruses (orthomyxoviruses) contain six to eight double-stranded RNA molecules.

Of the six structural polypeptides of the measles virus, the hemagglutinin (a protein on the surface of the viral particles) is important for attachment of the virus to the host cells. Antibody against the hemagglutinin neutralises the virus As measles infection produces life-long immunity, the hemagglutinin of this virus was considered to be highly stable, possessing only a single serotype. An attenuated measles virus (a suspension of weakened virus to produce active immunity) (Edmonston strain) is being employed as the vaccine strain throughout the world.

In a recent publication, M. J. Birrer and colleagues (*Nature* **293** 67) reported, for the first time, that the measles virus genome is also subject to mutation. This important finding has forced scientists to revise their knowledge concerning the biology of this virus. The present work raises doubts about the wisdom of using a single-strain vaccine without adequate knowledge of the precise antigenic variant of the measles virus circulating in a particular population.

The highly specific monoclonal antibody prepared by the hybridoma technology was used against the hemagglutinin. A large molecular weight protein may possess more than one antigenic determinant. Animals immunised with such a protein (immunogen) produce antibodies against these and the resultant antiserum is a mixture of antibody molecules capable of recognising different antigenic determinants of the same immunogen. Such antisera are not useful for determining minor variations in protein structure. But, the hybridoma clones produce antibodies against only a single antigenic determinant. Such monoclonal antibodies obtained from individual hybridomas may, however, react with different antigenic determinants of the same protein.

The authors produced two hybridoma clones (F/20 and H-1) producing antibodies against the hemagglutinin of measles virus. Further, they screened measles virus for antigenic variants. The monoclonal antibody and live virus were mixed, incubated and cultured for selection of any survivors.

Many survivors were obtained with the anti-hemagglutinin antibody (F/20). These were neutralised by the H-1 monoclonal antibody, indicating differential reactivity of these virus particles. These variants in the hemagglutinin gene were stable and, therefore, further structural studies were carried out. Employing the technique of peptide mapping, the authors showed that the variant and the wild-type virus differ by one, or only limited amino acid residues in the hemagglutinin molecules (mw 80,000). Further, they demonstrated that the measles virus genome is also subjected to mutation in nature.

This work, therefore, clearly emphasises the necessity of re-examining the differences between measles virus vaccine strains and isolates from particular populations under study. The study was limited to only two antigenic determinants, but mutations could also occur in other regions of the virus structural proteins, as is revealed by other researchers.

Another virus of importance, that of human rabies, had also been considered antigenically stable. Failure to protect exposed individuals had, so far, been attributed to low potency of the vaccine, or to a delay in commencement of treatment. Recently, however, employing the same methodology described above, the scientists have shown the presence of mutated glycoprotein in rabies viruses isolated from human cases of rabies. In laboratory experiments, the rabies vaccine could not protect animals against challenge with such mutants.

M. V. N. SHIRODKAR

J. M. DESHPANDE

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Cloning influenza virus genes in bacteria for influenza vaccine

SOME antiviral vaccines, such as those of polio, rabies and smallpox, are, usually, dependably effective. But, a similar vaccine against a rather mild viral infection, influenza, poses inherent problems due to constant antigenic variation in the virus. Hence, influenza must be maintained under constant global surveillance, including accurate antigenic characterisation of isolated strains. Vaccines currently employed contain a mixture of several strains of influenza A and B viruses so as to cover the known antigenic spectrum. New major antigenic variants must be added as they appear.

Most attenuated influenza virus vaccine strains are produced by recombination of a known attenuated virus with the epidemic strain. Following the production of a suitable recombinant virus strain, appropriate studies must provide evidence that the seed virus is free from extraneous viruses; that the virus is free from properties, affecting the nerve tissue for monkeys and is completely neutralisable by immune serum; that the volunteer studies provide proof that the virus is attenuated and that the virus is genetically stable. These tests are time-consuming and hence, by the time the attenuated influenza virus vaccines are ready for use, the virus normally "drifts" antigenically to a new form.

Tackling a flu epidemic

A novel approach to circumvent the problems arising from the use of a live virus for a vaccine is to express the antigenic determinants of the virus in a bacterial strain. Antigenic determinants of the fowl plague virus have been expressed in bacteria using a tryptophan operator/promotor system. Recently, I. Heiland and M. J. Gething of the UK have successfully expressed the human influenza antigenic hemagglutinin (HA) in bacterial cells (*Nature* 292, **851**). The procedure consisted of a series of sophisticated genetic manipulations, involving several enzymes. Plasmids, the extrachromosomal elements replicating autonomously, were used as the cloning vehicles.

The expression levels obtained at present were considerably lower (10 per cent) than those theoretically attainable. Also, the HA gene used in this work did not originate from an influenza strain which is currently causing disease. Nevertheless, the methods described are widely applicable and might possibly provide a basis for producing a vaccine against a current strain if the levels of expression can be increased.

The vaccine prepared by using the cloned copy of the hemagglutinin gene should bypass some of the drawbacks of the live viral vaccine mentioned above. However, extensive animal tests and human trials will still be required before the vaccine could be ready for actual immunisation. This would, once again, pose the problem of "antigenic shift" while the vaccine gets ready. The problem could, possibly, be solved by using DNA copies of the HA genes from various viral strains and by cloning them into one, or more, bacterial plasmids.

M. V. N. SHIRODKAR

S. V. GADRE

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Voids are also important!

COSMOLOGISTS have so far considered themselves lucky that the structure of the universe on a sufficiently large scale is relatively simple. This simplicity is seen in two ways. If we survey different directions, the overall structure of the universe is found to be the same. Thus there is no preferred direction. The second property, known as homogeneity, tells us that if we examine two different (even widely separated) regions of space we would find them similar in properties. These two properties were assumed by Einstein when he constructed what is now recognised to be the first in the modern line of model universes. The currently favoured big bang models of the universe also take these properties for granted.

However, theorists are vague when we ask the question: "What is the distance scale over which we should expect these simplifying properties?" A green lawn seen from a distance looks a uniform expanse of green; however, when we examine it closely at a smaller scale we detect inhomogeneities in the form of blades of grass. Read a 'galaxy' for a blade of grass and the 'universe' for the lawn and you will get the first crude idea of homogeneity.

But is the distribution of galaxies homogeneous in the universe? Previous studies showed that galaxies are largely distributed in clumps or clusters extending up to about 30 million light years. So, provided we are talking about distances larger than these we may call the universe homogeneous. The characteristic distances talked about by cosmologists are about 3,000 million light years. So homogeneity has been a good assumption to make

Recently, however, some studies have revealed that inhomogeneities in galaxy distributions may be as large as about 300 million light years in extent. In particular, Robert Kirshner, Augustus Oemler (Jr), Paul Schechter and Stephen Shectman from the United States have reported the discovery of a void of this size in space (*Astrophysical Journal Letters*, **248** 57, 1981). The void lies in the northern sky in the direction of the constellation Bootes.

The discovery of the void was made after the analysis of the number distribution of galaxies in three regions of the sky. All galaxies brighter than specified brightness limits were counted and the redshifts of most of them measured. When the histogram showing how many galaxies are in a given redshift range was plotted, a striking feature emerged. There was only one galaxy in the redshift range 12,000 to 18,000 km per second. According to Hubble's law which tells us that in the expanding universe the velocity of recession increases in proportion to distance, the above gap of 6000 km per second corresponds to a distance gap of about 150 to 300 million light years. (The uncertainty in the range of the gap arises from the present uncertainty of Hubble's constant.) Laterally also the gap extends over a similar distance.

Normally, if galaxies were distributed uniformly, we should have seen about 25 galaxies in a region of the size of the gap. However, we see only one. Is this statistically significant? The probability of this observed deficit coming about by chance is less than one part in a thousand million. Still Kirshner and his colleagues are cautious in drawing any conclusions on the basis of statistics alone.

Other instances of such inhomogeneities have been known before, although not on such a large scale and not in such a striking fashion. The current ideas of galaxy formation in the early universe will have to explain how such large-scale inhomogeneities come about. It is interesting to note, however, that inhomogeneities of just this size were predicted by Tommy Gold and Fred Hoyle in their theory of galaxy formation back in 1958. However, theirs was a steady state universe which is currently out of fashion! It is now upto the big bang pundits to produce a satisfactory explanation of this void. Meanwhile, Kirshner and colleagues are making more detailed studies of the void and its surroundings.

J. V. NARLIKAR

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Molecular genetics and cancer

THE DNA contained in chromosomes of a living cell is the key material governing the various functions in the living organism. Therefore, an understanding of gene regulation in higher organisms has been a major aim of molecular biologists. This is necessary to unravel the mysteries of differentiation (fetal development of a multicellular organism) and dedifferentiation (development of cancer). Combination of biochemical and bacterial genetics techniques has provided us with a detailed understanding of the functions of bacterial genes. However, this was not so far possible in case of higher organisms since the mammalian genome is at least a 1000-fold more complex than that of bacteria and also because of the restricted techniques that were available for deciphering such a complex genetic material—DNA.

Today, almost all the cancer-causing chemicals in bacteria have been associated with mutational changes in DNA. However, so far only a few consistent aberrations in the chromosomes have been implicated in human cancer. Now, newer techniques like the recombinant DNA technology and DNA sequencing are available which may help to probe directly into the arrangement of the genetic material in any specific type of cancer in comparison with its normal counterpart.

In one of the first reports of its kind (*Nature* **293** 146), P. Humphries has demonstrated a degeneration of satellite DNA sequences (a fraction of DNA of an organism, which has a different density from the rest, and is usually made up of highly repetitive sequences of DNA) in cancer of human gastrointestinal tract in comparison with those from the corresponding normal tissue of the same patient.

The satellite DNA is a unique characteristic of DNA of the higher organisms. It consists of millions of copies of very short nucleotide sequences which are arranged one after another, but which have undergone some divergence, so that the other hierarchies of repeat size can be detected by hybridisation techniques. The functions of satellite DNA are as yet speculative. However, with the available techniques, it is relatively easy to find differences, if any, in sequences of the satellite DNAs.

Humphries used human fetal liver DNA to prepare a satellite DNA consisting of about 100 fragments. He then used this probe to compare the complementary sequences of satellite DNAs from histologically normal human gut mucosa and from gastrointestinal cancer from the same patient. The results showed that some of the hybridising sequences of satellite DNA from normal gut mucosa were no longer present in the corresponding satellite DNA from the gastrointestinal cancer.

Of the five individuals having gastrointestinal cancer, satellite DNAs from tumours of two patients showed identical patterns, whereas DNAs from cancers of two others had quite different patterns. But, all of these differed significantly from their normal tissue counterparts. In contrast, however, no differences could be detected between satellite DNAs from normal and cancerous tissues in one case. According to Humphries, comparison of such satellite DNA patterns between normal and cancerous tissues should lead to assess their significance and usefulness during onset of the disease. Further, if such changes could be associated with leukemias, a quantitative molecular genetic probe would be available for monitoring the disease during therapy.

It must be emphasised that the biodeciphering of molecular genetics in the mammalian genome is much more complicated. Besides, there is a lot of individual variation in the patterns of satellite DNAs of normal gut mucosa. It may also be pointed out that in one case of colon cancer, no differences could be detected in DNAs of normal and cancerous tissues. Nevertheless, a distinctive satellite DNA pattern of cancerous tissues was obtained in the other four cases when compared with their normal counterparts. The apparent rapid variability in the amount of satellite DNAs and their chromosomal locations may provide a means of altering the overall genotype resulting in an abnormal growth. These few findings on satellite DNAs in gastrointestinal cancers may or may not hold good in other human cancers. However, the lead given by him needs to be pursued, for there is much more to be learnt about the human genome.

M. V. NARURKAR

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A new insight into photosynthesis

PHOTOSYNTHESIS is the process by which green plants trap solar energy and convert it into chemical energy. The energy requirements of all living organisms are ultimately met by this energy trapped by plants. Photosynthesis is a highly complex and multistage process which reduces carbon dioxide to carbohydrates with the help of light.

Light is absorbed by matter in multiples of specific amounts called quanta. In photosynthesis, their energy is converted into chemical energy in the form of adenosine triphosphate (ATP), also called the energy currency of the cell. Photosynthesis also produces reducing equivalents. Two pigment systems must be excited to perform efficient photosynthesis: photosystem I (PS I) consisting mostly of chlorophyll *a* and the other, photosystem II (PS II), containing a major part of chlorophyll *b* and other auxiliary pigments. Efficient photosynthesis also requires the absorption of an equal number of quanta in PS I and in PS II. Cytochromes, the complex iron-containing proteins in the plant cells, function efficiently as electron carriers in biological redox reactions along with other oxidation-reduction catalysts such as plastoquinone (PQ), which is the most important.

The two photosystems carry out two types of energy conversions, cyclic (involving only PS I) and noncyclic (linear—involving both PS I and PS II) photophosphorylation. In the cyclic process, the quanta of light, on interacting with PS I, induce a cyclic electron flow giving rise to a proton gradient which drives ATP synthesis. Linear photophosphorylation, discovered by D. I. Arnon in 1959, not only produces ATP but also free oxygen and the reduced form of nicotinamide adenine dinucleotide phosphate (NADP) A refined version of linear photophosphorylation is the Z scheme (named so because of the shape of the graphs of the oxidation-reduction potentials involved).

The presently accepted Z scheme of photosynthetic electron transport involves oxidation of water through the cooperation in series of the two photosystems. The PS I and PS II are linked by plastoquinone whose main function is to transport protons from the outside to the inside of the chloroplast membrane. The protons liberated from water oxidation and subsequent movement of protons to the inside by plastoquinone generates a *p*H gradient which is used for making ATP According to the Z scheme, PS I and PS II should exist spatially close together in the chloroplast membrane and in more or less equal quantities for linear electron transport.

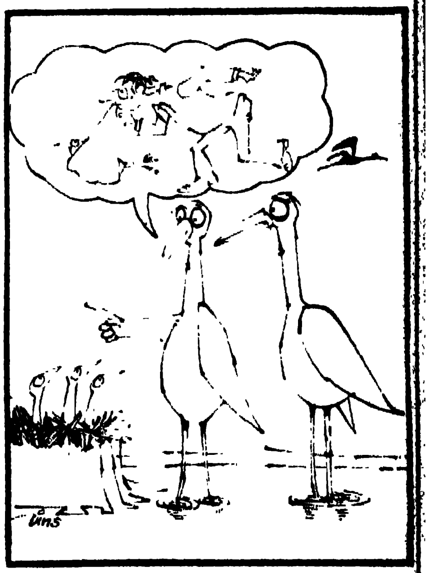
Prof. Arnon and his colleagues have challenged the Z scheme from time to time. In their recent paper (*Proceedings of the National Academy of Sciences*, USA **78** 2942), they have demonstrated, using ESR techniques, that there is no involvement of PS I in transporting electrons from water to ferredoxin. They have also shown that reduction of NADP or ferredoxin from water can be inhibited by antagonists of plastoquinone. But more interestingly, the reversal of this inhibition by compounds that permit proton movement across the membrane has also been reported. They, therefore, argue that plastoquinone could not be functioning as a link between the PS II and PS I but it may rather be involved in transporting protons liberated during water oxidation. Based on these and some other observations, they have postulated a new scheme called "oxygenic photosystem".

The main features of the new scheme are that ferredoxin is reduced by PS II and the function of plastoquinone is to translocate protons arising from water oxidation to the inner space. In their new scheme the PS I has been assigned the function of only cyclic phosphorylation and is designated as the "anoxygenic photosystem".

The main question is whether the new scheme can replace the Z scheme. It could, provided it explains a great deal of well documented data. And, of course, if the observations reported by Arnon and his colleagues are reproducible by others. It is a well-known fact that plastoquinone antagonists block almost completely the reduction of ferredoxin in an uncoupled system. The antagonist concentration used by Arnon and his colleagues is apparently inadequate. The new scheme fails to explain this as also the enhancement of NADP reduction in isolated chloroplasts, observed even by Arnon and his colleagues. Also, it is inconsistent with several other observations and hence scientists working in this area will be hesitant to accept it. However, considering the valuable contributions made by Arnon in the past 25 years, his proposals must receive due consideration, though it is highly unlikely that the new scheme will be proved correct.

P. V. SANE

Dr. Sane heads the Agricultural Biochemistry section of the Biology and Agriculture Division of BARC, Bombay. Photosynthesis is his special area of research.



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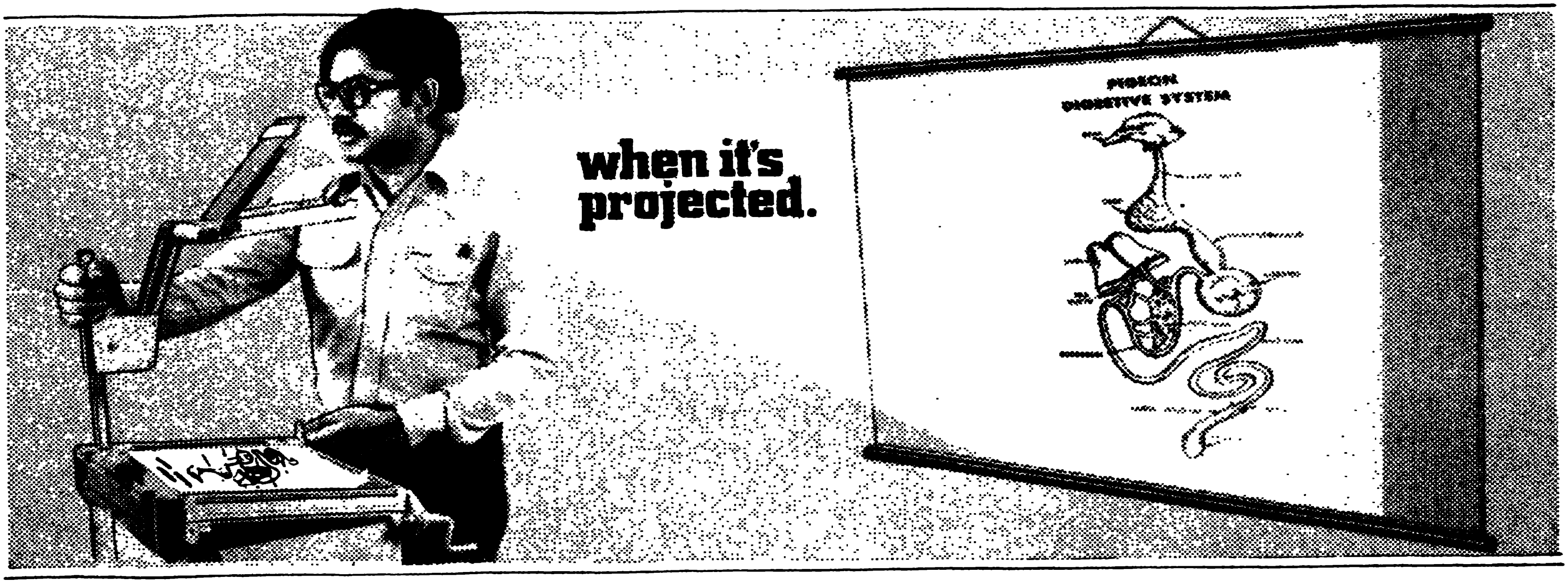

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Can storm surges be predicted?

[illegible] been used to simulate storm [illegible] tidal flooding in a cyclone

ABOUT 500,000 lives were lost in one of the most severe cyclones that hit Bangladesh (then East Pakistan) in November 1970. The Andhra cyclone devastated the eastern coast of India, killing about 10,000 persons in November 1977. Though cyclones occur all over the world, the Bay of Bengal is one of the ideal tropical cyclogenesis areas. And most of the cyclones occur in October and November.

Tropical cyclones and hurricanes strike certain low-lying coastal regions around the world every year, causing heavy loss of life and property. They have occurred in all oceans except the South Atlantic. They are known by various names—hurricane in the North Atlantic, Carribean Sea, Gulf of Mexico and Eastern Pacific, typhoon in the western North Pacific, 'Willy-willy' in Australia, and 'Baguio' or 'Daruio' in the Philippines; elsewhere, they are just called tropical cyclones. Several countries give special names to these storms. For instance, the US National Weather Service identifies hurricanes by the names of women—Belle, Camille, Gracie, Kathleen, etc. Hurricanes are named alphabetically every year starting from the beginning of the year. In the Indian subcontinent, tropical cyclones are named after the place of landfall (the place at which the cyclone strikes the coast), for example, the Chirala cyclone, the Chittagong cyclone, etc.

Cyclones are large vortices in the atmosphere, extending from 150 to 1,200 km, in a horizontal direction with fierce winds spiralling around a central low pressure area. A cyclone covers roughly a distance of 300 to 500 km per day. The maximum wind speed associated with a mature cyclone could be as high as 150 to 250 km per hour. The highest wind speeds in cyclones which have hit the Indian coast in the past 100 years have been about 220 to 240 km per hour.

The formation of the cyclones in the Bay of Bengal is strongly related to the seasonal migration of the Intertropical Convergence Zone—the zone of low pressure and convergence of the trade-wind easterly systems of the two hemispheres, across the bay. This zone migrates seasonally as far as 15° or more north and south of the equator in some places; it reaches its northernmost point in September and southernmost in March, corresponding to the seasons of highest temperatures in the oceans. When it is at or near its seasonal maximum displacement, the Intertropical Convergence Zone plays a part in the formation of tropical cyclones.

The processes leading to the formation of tropical cyclones are not well known, although several plausible theories have been presented. For cyclonic wind circulation to develop, air currents near the ground must start to converge (as happens in the Intertropical Convergence Zone) and accelerate the process of rotation, which is related to the rotation of the Earth about its axis. Since this rotation becomes negligible at the equator and is very small within some hundreds of kilometres from there, cyclones rarely form between latitudes 5°N and 5°S, though there are a few exceptions—for example, Sri Lanka cyclones of 28 November 1922 and 20 December 1964. Further since the life of the tropical cyclones depends on their uptake of heat and moisture from the ocean, they cannot develop over sea surfaces with a temperature less than 26°C. Therefore, tropical cyclones generally form between 5°N and 15°N in the warm waters of the Bay of Bengal along the Intertropical Convergence Zone.

The formative periods of tropical cyclones are spent over the sea. Drawing energy and moisture from the warm sea, they intensify to full strength and move west, north-west or even north to hit the east coast of India. Of the storms that develop in the bay, over 50 per cent approach or cross the east coast in October and November and 30 per cent in the premonsoon season. An important feature is that, along a vast stretch of the east coast of India, there are a few strips which are more vulnerable to tropical cyclones. These areas are

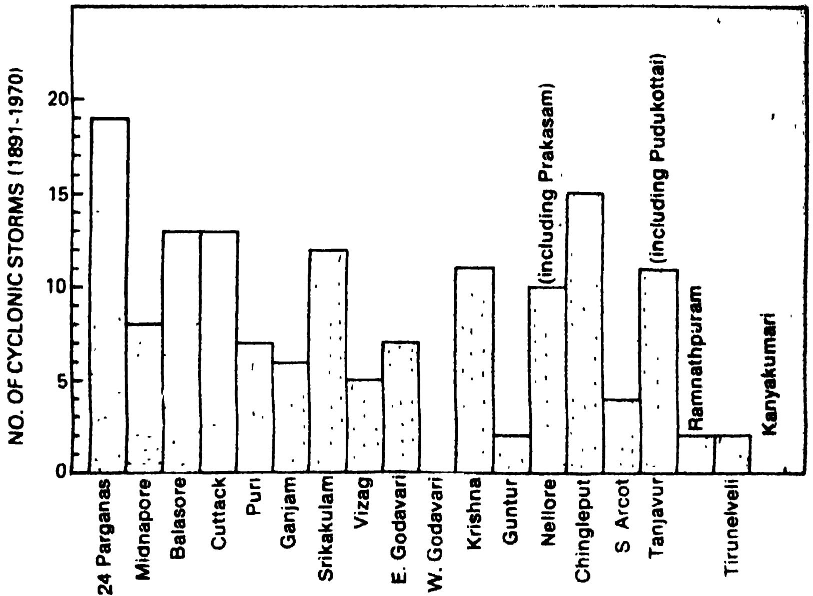

Fig. 1 Cyclones in the coastal districts on the east coast (Courtesy: India Meteorological Department)

shown in Fig. 1, which provide the landfall of cyclonic storms on a districtwise basis. Very frequently, these cyclones change their tracks and recurve towards the north-easterly/east-north-easterly direction to strike the coasts of Bangladesh and Burma.

Surge phenomena

It is the "storm surge" which is the most destructive element associated with intense tropical cyclones. Most of the human disasters caused by tropical cyclones have been attributed to storm surges. A storm surge is an abnormal rise of sea level caused by a cyclone moving over a continental shelf. A surge is caused by the interactions of air, sea and land. The cyclone provides the driving forces in the form of a very high horizontal atmospheric pressure gradient and very strong surface winds. As a result, the sea level rises and continues to rise as the cyclone approaches the shallow water, and reaches a maximum on the coast near the point of landfall.

The storm surge at any place may be divided into three stages—forerunner, the main surge, and resurgence. A forerunner is the gradual rise of sea level preceding the main storm; even when the cyclone is far from the coast, some broad-scale disturbances seem to produce variations of coastal sea level. The main surge follows after the storm surge rises to its peak; the period of the main surge at a place varies from a few hours to more than two or three days, depending on the speed of the cyclone. Resurgence follows the main surge. The sea level gradually tends to return to the normal state in this stage. It includes, however, various kinds of oscillations due to topographic and other effects. The resurgence may sometimes continue for two or three days. Resurgences are also hazardous, particularly for marine and inland shipping. Surge waves inundate vast stretches of coastal area and wash away all that comes in their way. During the 1977 Andhra cyclone, the surge water extended inland up to about 12 km, affecting Divi, Edurumondi and Eletidibba islands at the estuary of the river Krishna and the main coast south of Masulipatnam. The tidal bore went up the river Krishna and flooded the embankments as far north as Repalle taluka. Fig. 2 shows the areas affected by surge waves.

Littoral countries of the Bay of Bengal

Statistics show that only about 15 per cent of the global tropical cyclones form in the Bay of Bengal; they are known to be of shorter life (2 days to 7 days) and less intense than hurricanes and typhoons. Even so, countries surrounding the Bay of Bengal (India, Bangladesh and Burma) suffer most in terms of loss of life and property caused by the surges. The reasons, besides the lack of adequate and accurate prediction, are the low lands all along the coasts and the considerably low-lying large deltas such as the Gangetic and Irrawaddy deltas. The 1876 Bakhergunge cyclone, which moved inland between Calcuta and Chittagong, produced a surge about 12 metres high, engulfing several islands and coastal areas; over one hundred thousand people drowned. Looking at the enormity of the loss and rehabilitation costs, the government of the day decided to set up a meteorological department for the country to minimise the loss of lives on account of floods.

One of the most severe cyclones hit Bangladesh in November, 1970. About 500,000 lives were lost. The damage to property was colossal. Near Chittagong, the sea surface rose by 6 to 9 metres. About 65 per cent of the total annual fishing capacity of coastal areas was destroyed.

The November 1977 Andhra Cyclone, which hit the eastern coast of India, killed about 10,000 persons and caused an estimated loss of Rs. 200 crores. The height of the surge waves was estimated to be more than 5 metres. The tidal waves entered as far as 12 km inland. Four severe cyclonic storms struck the Burma coast during the last decade, the Bassein storm of May 1975 being the most intense. The surge induced by the storm inundated land extending up to 95 km from the Irrawaddy delta region. According to local authorities, the highest water level of about 5 metres occurred not along the shoreline but about 50 km inland; the surge water had penetrated deep inland through the large river systems and estuaries joining the Irrawaddy deltaic area. Table 1 lists the number of deaths associated with cyclones in which death tolls exceeded 5,000 lives. Of the 20 major cyclone disasters, 14 occurred in India and Bangladesh. And about 67 per cent of deaths took place in India and Bangladesh. The casualties would have been considerably lower if the surges could have been predicted, say, 24 hours in advance. The prediction must, of course, be accurate enough so that one can distinguish between dangerous surges and the surges that cause little harm; people cannot be evacuated for every approaching storm.

Factors responsible for devastating surges in the Bay of Bengal

What are the factors that cause severe flood situations in the Bay of Bengal region? The surge height is inversely proportional to the depth of water, that is, the deeper the water, the shorter the surge height. When a cyclone is in deeper waters away from the coast, the surge is not very high. This is because the wind cannot produce a strong motion in deep

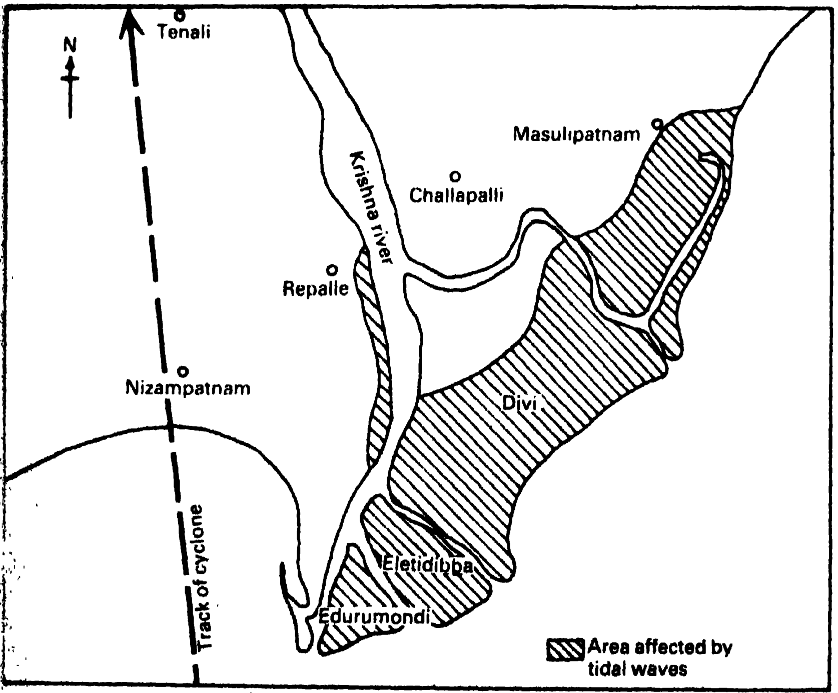

Fig. 2 Tidal inundation due to the Andhra Pradesh cyclone in 1977

waters. As the cyclone approaches the shallow coastal water, the surge begins to amplify. It is easier for winds now to stir almost the whole depth of the shallow water. Besides, as the water is driven from a deeper region to a shallower region, the water level must go up because of mass conservation. Since much of the northern Bay of Bengal is less than 10 metres deep, it provides a favourable condition for surge amplification. And the bay gradually converges to the north. Because of this converging nature, a storm blowing straight into it may funnel the water towards the north (depending upon the track of the cyclone). Convergence then leads to the piling up of a strong surge in that area as the water driven or funnelled towards the northern part of the bay cannot escape sideways. If the arrival of the surge also coincides with high tides, extensive flooding may occur due to a non-linear tide-surge interaction.

In the northern part of the head bay are numerous small islands and five large islands. These islands are thickly populated and the coastal areas are generally less than 5 metres above the mean sea level. These islands may act as agents to amplify surge water in the channels lying between them because of mass conservation reason.

One of the world's major river systems (Ganga-Brahmaputra-Meghna) meets the Bay of Bengal in its north-eastern corner. Besides this, a number of other major rivers flow into the bay along the east coast of India. The enormous discharge of fresh water carried by these rivers may modify the tide and surge situations. Further, the presence of such a large number of waterways may help a surge originating in the bay to penetrate deep inland. A consequence of this is the reversal of the flow in these rivers, causing inland flooding and saline water intrusion. Saline water intrusion through the Hooghly seriously affects the supply of drinking water to Calcutta and most of the other towns and cities situated along the coastal rivers. The salinity also affects the fertility of the land, affecting agriculture in the coastal areas.

Devastation caused by storm surges

ONE OF the earliest cyclones documented in historical records foiled the Spanish attack on the lower Carolina settlements in the USA on 4-5 September 1686. The Spanish Armada, which landed near North Edisto Island on 4 September and was heading towards Stuart Town near Beaufort, had to abandon the attack due to gale-strength winds (wind speed more than 17 metres per second) of the cyclone. The Gulf of Mexico and the east coast of the US are concave in shape and are therefore vulnerable to storm surges. In 1969, hurricane Camille generated a 7.4-metre high surge in the Gulf of Mexico, which was one of the highest ever recorded in the US. Another severe cyclone struck the Gulf of Mexico near the Texas, Louisiana border on the night of 26-27 June 1975. A surge height of 3 to 5 metres was reported along the coast and the ocean waves entered the lowlands 50 to 100 km inland.

In Japan, surges quite frequently exceed heights of 2 metres. On 26 September 1959, a typhoon moved over Ise Bay and whipped up a peak surge of 3.6 metres near Nagoya. Another typhoon produced a surge of 2.5 metres near Osaka in Osaka Bay on 16 September 1961. Several surges have occurred in Korea. A cyclone of severe intensity struck the western coast of Korea on 29 July 1965, generating an unusually large surge of about 5 metres.

Nearer home, Hong Kong harbour experiences three to four storm surges every year. On most occasions, the surge height does not exceed 2 metres but some had gone up to 3 metres. Typhoon Lucy produced a surge of 3 metres in July, 1971. South China also experiences major surges every year. In 1881, a typhoon struck the South China coast, drowning about 300,000 people.

Coastal regions in Thailand face one to two major surges every year. Maximum surges of 4 metres have been reported from this region. The Philippines also experiences pronounced storm surges every year. A cyclone which struck the towns of Leyte and Cebu in October, 1912 generated the surge of about 9 metres in Sogod Norte.

Considerable damage is caused every year in Australia due to storm surges. One of the earlier cyclones which passed over Bathurst Bay and hit Barrow Point on the eastern coast of Queensland on 5 March 1899, caused an exceptionally high surge which rushed 5 km inland. Two cyclones of great intensity occurred in recent times. The first one, Althea, struck the Queensland coast on 24 December, 1971; it raised a surge of about 3 metres in Townsville harbour. The second cyclone Tracy destroyed Darwin, the main port on the north coast of Australia, on Christmas Day in 1974. However, the peak surge associated with this cyclone was only 1.6 metres. Most of the damage was caused by strong winds.

S.K.D.
M.P.S.

Storm surge predictions

Can storm surges be predicted? There have been attempts to develop empirical methods for forecasting storm surges in the Bay of Bengal. In the absence of adequate data, these methods have not been useful. One of the possibilities is to solve the hydrodynamic equations governing the motion in the sea. These equations include some non-linear, partial differential equations for which the mathematical theory is very limited. As a result, an analytical solution of the general equations is not possible without making major simplifying assumptions in which many important parameters may have to be dropped. If we look into the storm surge equations, that is, equations of motion and continuity, we find that the main parameters governing the forces are: (i) the Coriolis force, which appears as a result of the Earth's rotation, (ii) the pressure gradient force, (iii) the surface wind force, and (iv) bottom stress arising as a result of sea bed friction. Additionally, we have acceleration terms in the equations of motion. The assumptions usually made for analytical solution are:

1. The effect of the Earth's rotation is dropped in many cases to simplify the equations,
2. The wind field associated with the cyclone is assumed to be uniform and steady, which is not the case in reality,
3. Frictional effects, which play a significant role in shallow waters, are dropped in many analytical models,
4. Non-linearity arising in the acceleration terms is dropped and the surge is described by linear equations with time-independent coefficients. This non-linearity phenomenon becomes very noticeable in shallow waters such as in northern parts of the Bay of Bengal, and
5. Finally, the sea is considered as a channel of uniform depth or a two-dimensional basin of uniform depth with straight coastal boundaries. Variable depths are difficult to handle theoretically, because the equations will no longer have constant coefficients. Similarly severe difficulties are encountered in the discussion of models with complicated coastal boundaries.

The analytical solution is obtained either by the perturbation method or by applying integral transforms to the partial differential equations. The solution of these unsteady equations determines the surge heights as a function of space and time and thus

the surges can be estimated at any place at any instant of time.

The best alternative is the numerical solution of the hydrodynamic equations. The method of numerical prediction is based on a numerical integration of the hydrodynamic equations governing the motion in the sea. This method is also applicable when the forces and the boundary conditions are described by very complicated functions, as is almost always the case in reality. For practical forecasting, it is superior to the analytical methods which can handle certain simple types of surges.

The general system of equations that represent storm surges has been treated numerically with success during the last two to three decades. One of the first efforts in this direction was made in 1954 in which the computation was done by manually operated calculating machines. With the advent of modern computers and the development of sophisticated numerical techniques, great strides have been made in surge forecasting.

In some countries, for example, the US and Japan, where severe cyclones are common, a reliable system of prediction of storm surges has been evolved. The approach has been to formulate a set of differential equations governing the motion of the sea by incorporating the driving forces and the bottom stress, and solving them numerically. The numerical technique consists of solving the governing equations at a discrete set of points in space, at discrete instants of time. The numerical models can predict surge, its development and the spatial variation of the resulting sea surface elevations from a knowledge of the basic parameters describing the developing cyclone and its track. A SLOSH (Sea, Lake and Overland Surges from Hurricanes) surge model has been developed for real-time operational forecasting of surges on the US open coast in space and time. In India, such a study was pioneered by the scientists of the India Meteorological Department in 1972. Since then, a number of Indian and other researchers have developed several numerical models for prediction of the surges in the Bay of Bengal region.

In all these studies related to the bay, the coast line is approximated by conventional orthogonal straight line segments (stair step). The manner of this boundary construction is illustrated in Fig. 3. Experiments have shown that the surge is sensitive to the way the coastal boundary is constructed. An effective means of achieving greater accuracy is a more precise representation of the natural shoreline which is curved and/or broken by the bay or estuaries. In storm surge work, curvilinear boundary representation, depending on the application of conformal mapping (this property means that angles are preserved in projection and, therefore, forms or shapes of small curvature of the natural shore-line remain the same), has previously been considered by some workers for other regions of the world. Scientists at the Centre for Atmospheric and Fluids Sciences, Indian Institute of Technology, New Delhi, have very recently developed a numerical storm surge prediction model for the Bay of Bengal which, for the first time, is capable of dealing with curved coasts. The treatment of coastal boundaries in this involves a procedure leading to a realistic curvilinear representation of both the western and eastern sides of the Bay of Bengal (Fig. 3). This coastal representation has another added advantage of taking automatically into account the finer resolutions in the shallow waters of the northern bay. **The model is fully non-linear and has** successfully been used to simulate the surges generated by the 1977 Andhra cyclone. The analysis area of the model covers almost the entire Bay of Bengal (6°N to 22°N) and therefore the model is fully able to simulate the effect of three days (16 to 19 November, 1977) of the surge-generating capacity of the cyclone before landfall at the Andhra Pradesh coast. Using available data on the Andhra cyclone as a guide in representing the effect of wind-forcing in our model, we compared the predicted rise in the sea surface with estimates based on reports received from Andhra Pradesh after the disastrous flooding in that region. The predicted peak surge compared well with the 5-metre surge height reported along parts of the Andhra coast south of Masulipatnam. Fig. 4 shows the simulated coastal surge profile at the time of the highest surge. This model is also found to be validated by the data available for the 1975 Burma cyclone which hit the coastal region near Bassein. This study may help to give advance warning to prevent extensive storm damage in the future, such as that caused by the 1970 Chittagong or the 1977 Andhra cyclones.

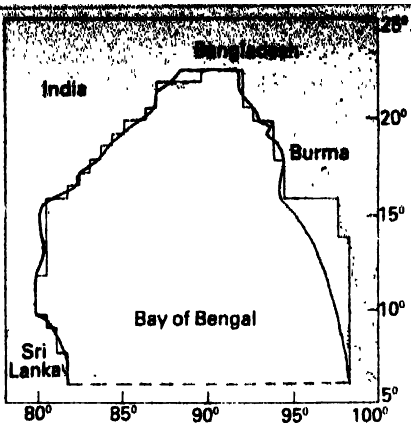

Fig. 3 Stair step boundary configuration and curvilinear representation

Table 1. Deaths associated with noteworthy tropical cyclone disasters

Year	Location	Deaths
1970	Bangladesh	500,000
1737	India	300,000
1881	China	300,000
1923	Japan	250,000
1897	Bangladesh	175,000
1876	Bangladesh	100,000
1864	India	50,000
1833	India	50,000
1822	Bangladesh	40,000
1780	Antilles	22,000
1839	India	20,000
1789	India	20,000
1965	Bangladesh	19,279
1963	Bangladesh	11,520
1961	Bangladesh	11,468
1977	India	10,000
1963	Cuba-Haiti	7,196
1900	Texas	6,000
1960	Bangladesh	5,149
1960	Japan	5,000

(Courtesy: Bangladesh Meteorological Service)

While the accurate prediction of surge is very important, it is also necessary to have an idea of the extent of inland inundation for evacuation of the population. Keeping this in view, scientists at the IIT, New Delhi, have developed a river-ocean coupled model to study the dynamic effects of river systems joining the east coast of India. In the western boundary of the bay, the model includes a dynamic representation of the main rivers, Hooghly, Mahanadi, Krishna, etc. This model shows that the surge water can penetrate deep inland through the estuaries, causing reversal of flow in the rivers and hence inland flooding. This model may help in predicting the extent of inland penetration of surges originating in the bay.

Another model has been developed for the prediction of inland inundation along Indian coasts. Frequently, the lateral boundaries in numerical storm surge prediction models are taken to be vertical solid walls through which there is no flux of water and many such studies have been undertaken. In reality, however, the water will usually move continuously inland and the use of idealised vertical solid walls may lead to misrepresentation of the surge development. Hence, instead of using the conventional solid wall boundary at the coast, our model uses a continuously deforming lateral fluid boundary and includes the coastal topography in order to route the storm surges over the land. The model has been tested with idealised coastal topography along the east coast of India. A model is also being developed for predicting the surges along the west coast of India.

Cyclones in the Bay of Bengal will continue forming and hitting the Indian coast. It is not possible to stop this process of nature. What one can do is to try to predict such cyclones and their magnitude to minimise the loss of life and property. Each model developed has its own utility and limitations; the existing models could be further refined. Even in the most sophisticated numerical models, the utility would depend much on the accuracy of the forecast of the meteorological input parameters—pressure drop, direction and speed of the movement of the storm, maximum sustained winds and the radius of maximum winds. Besides meteorological inputs, the model requires the knowledge of the bathymetry (sea-bed contours) of the region of interest. For want of adequate data of storm surges, the validation of the model becomes difficult. Difficulties are also experienced in constructing the wind field of a real cyclone because of the absence of observed data. Meteorological satellites have, however, brought many advantages, including the ability to detect tropical storms over those ocean areas which previously had to be considered as data-sparse regions.

Indian meteorologists receive satellite reports on the intensity and movement of tropical cyclones from the National Environmental Satellite Centre at Washington, DC and the joint Typhoon Warning Centre at Guam. These data are utilised for prediction purposes. Now that India is venturing into satellite-based studies, it is hoped that relevant information would be readily available on meteorological input parameters needed for storm surge prediction. With the advent of large computer systems, it is now possible to solve realistic models for storm surge prediction using sophisticated numerical techniques. And based on these discussions, the following recommendations could be made.

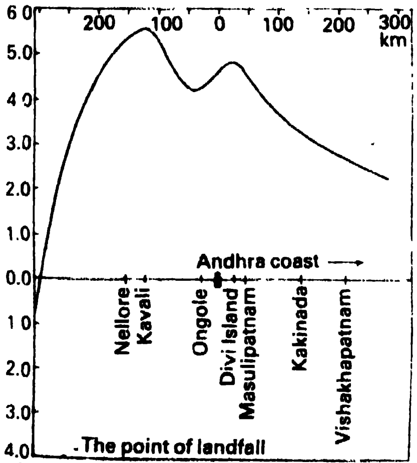

Fig. 4 Surge profile at the time of the highest surge on the coast

1. In order to improve the accuracy of the forecasts of meteorological input parameters required for surge prediction, India should acquire aircraft capable of making dropsonde (instrument which when dropped from the aircraft gives a continuous record of vertical profile of temperature, humidity and wind over the region) measurements in the vicinity of the centre of a cyclone when it is still over the sea.

2. We do not have tide recorders capable of measuring high tides and therefore the estimate of the storm surge is mostly done on post-storm surveys of the areas inundated by sea water. This lacks accuracy. It is therefore an immediate need to have modern instruments such as autographic flood gauges and tide telemeters installed at a number of locations along coasts vulnerable to surges. Automatic tide gauges will provide more precise tidal observations. Float-type of tide gauges are widely used as standard instruments for continuous and accurate observations of tides in many countries. Many of them are roll-type in which the rise and fall of the tide is recorded by a pen moving horizontally along a guide-rail on a rotating drum placed horizontally. The instrument is installed atop a tidal well and sea water is conducted into this well by a tube. The variation of sea level in the well is measured by the vertical motion of a float and recorder on a self-recorder (Fig. 5). These gauges are soundly structured with small instrumental errors and are convenient for long-term recording of observations. Other instruments widely used by many countries for operational use are tide telemeters or remote-recording tide gauges.

3. Following the procedure outlined by the World Meteorological Organisation in 1978, a detailed post-storm field survey should be undertaken as soon as possible after the land flooding recedes and order is restored. A practical overview of flooding and damage by field survey will be a valuable complement to available data. According to the procedure, the survey team is advised to visit the local administration as well as the local fishermen. A surveyor should also make an effort to collect objective information by contacting eye-witnesses of the actual situations which occurred at the time of flooding by storm surges. The high-water mark information may be had from visible marks, which are left on walls inside houses and other objects in a village. The time at which the sea level was the highest is an important piece of information obtained from eye-witnesses.

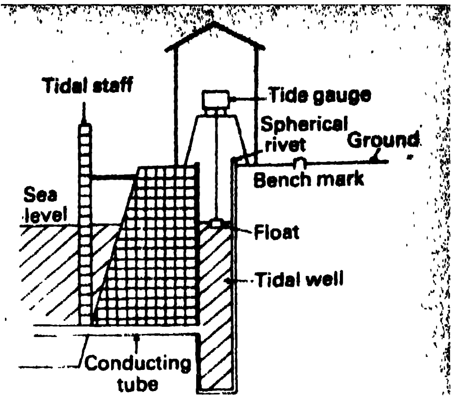

Fig. 5 A typical tidal station

4. Efforts should be made for real-time exchange of information regarding storm characteristics monitored through satellite imagery and coastal radars.

5. The development of a numerical model for the prediction of storm surges along the west coast of India which is also affected by severe cyclonic storms must be taken up.

6. Existing models must be improved to include non-linear effects of tide-surge interaction.

Dr. Dube is Senior Scientific Officer at the Centre for Atmospheric and Fluids Sciences, Indian Institute of Technology, New Delhi. After doing his Ph D in fluid mechanics from Lucknow University, Dr. Dube joined the Meteorological Services of India in 1972, where he was associated with the operational and research wings of the India Meteorological Department. He joined IIT-Delhi in 1978, and is now working on storm surges and oceanic waves.

Prof. Singh heads the Centre for Atmospheric and Fluids Sciences and is Professor in the Mathematics Department, IIT-Delhi. He obtained his Ph D in fluid mechanics from the University of Maryland, USA. He was the University Grants Commission National Lecturer in Mathematics during 1976-77. Prof. Singh has helped develop multi-disciplinary activities like meteorology and biomechanics in academic institutions in India.

Peened shafts for better sealing

SEALS are a vital part of fluid systems. Because most seals appear simple, their importance is often overlooked. They contain fluid where wanted and prevent it from entering unwanted areas. Leaks from pipe-flanges, and stuffing boxes of pumps and joints of all kinds cost industry a large amount of money every year. A system may even fail completely because of a single critical leak.

Trying to minimise leakage may increase friction and power losses, so a good design has to seek a compromise and even small improvements may prove important. James D. Simons, a mechanical engineer at the General Motors Research Laboratory, USA, has studied a way to minimise friction at sealing lips (*Design Engineering*, **52** 4, 32). He has found that sealing is better if the surface of a rotating shaft is peened—hardened by hammering or bombarding with hard shot—rather than plunge-ground, the normal practice in which surface finishing is carried out by a radially moving grinding-wheel.

There are basically two types of seals, dynamic seals and static seals. Dynamic seals prevent leakage through parts in relative motion; static seals prevent leakage through parts at rest. In dynamic seals, a thin film of the fluid medium being sealed lubricates the sliding faces at the seal. In one type of dynamic seals, the contact seals, the fluid film generated between the parts in relative motion at the seal is very small—of the order of one to three microns. In the other type, the clearance seals, the gap, which is preset, is much larger—of the order of about 25 microns. Consequently, the leakage is larger for clearance seals and their use is limited to special situations in which leakage can be tolerated but not seal failure, for example, in the steam turbines used for power generation. Simons' work concerns the most widely used contact seal, the dynamic rotary lip seals commercially known as oil seals or shaft seals.

In a dynamic rotary lip seal, a V-shaped knife-edge sealing lip presses against the shaft and prevents leakage. A spring, known as a Garter spring, supplements the contact pressure, and a rubber case with a bonded metal insert stiffens the seal and protects the lip. The sealing lip runs on the thin film of fluid lubricant. The thickness of the film is controlled precisely by the mechanical pressure of the sealing lip and the surface finish of the shaft. If the film thickness is too high the fluid leaks; if too low, the sealing lip wears out and the heat generated increases, which can lead to oscillations where the seal alternately sticks and slips.

It is customary to plunge-grind the shaft to a surface finish of 0.2 to 0.5 microns CLA (centre line average), because the lip wears out faster for rough shafts. However, Simons recommends peening instead of plunge-grinding. A peened surface has gentler slopes, and a high radius of curvature for asperities (protrusions, the lower the radius the sharper the protrusions—Fig 1) This helps to trap the oil and reduce friction.

Simons' process of peening is also less expensive than the conventional blast peening process in which small steel balls are made to impinge on the metal part at high velocities and in a closed chamber. In Simons' process, the shaft surface is finished by shot peening with a flap-brush wheel, which consists of radially extending fibre-flaps impregnated with cast-steel shots and bonded to the rigid fibres Shot sizes, chosen for correct indentation, were between 0.3 and 0.8 mm. The process of peening has to be carefully designed to get the correct size and spacing of the asperities on the peened surface to match the seal material chosen The direction of the slope of the asperities must also match with the direction of rotation of the shaft

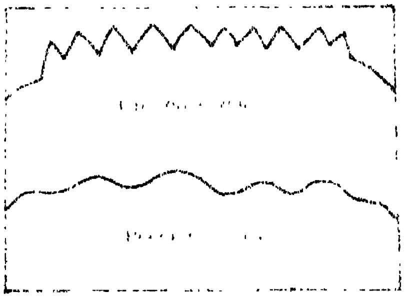

Fig. 1 A peened surface has gentler slopes, flatter asperities (high radius of curvature) than a ground surface; peening shafts, therefore, reduces friction (asperities exaggerated)

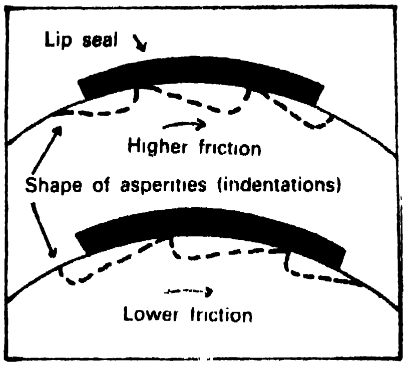

Fig. 2 The slope of asperities on the peened shaft must match with the direction of shaft rotation (asperities exaggerated)

Microscopic spiral grooves are also formed when the shaft is shot peened The grooves act like a screw-pump, pumping in the direction opposite to that of the leakage—a beneficial side-effect. The pumping action also reduces friction substantially, and allows much lighter lip loading without sacrificing sealing ability The whole process, however, has one drawback—at lower shaft speeds, dynamic sealing is not very effective.

B. D. VYAS

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Polarisation flow meters for easier and cheaper measurements

THE rate of fluid flow is one of the most important parameters of the various process variables. Accurate flow measurement, essential to keep a close check on plant efficiency wherever fluid flow is involved, is especially necessary in biomedical engineering, aerospace applications, nuclear installations, and power generation units Recently, Richard A Formato, a US consultant, has patented a new flow meter which combines the principles of two kinds of meters already in use. The new meter, not yet tested, combines the concepts of electromagnetic and magnetoelectric induction simultaneously to give a better and probably cheaper device.

The measuring principle of an electromagnetic current meter is based on the measurement of the intensity of the electric field which can be induced by a magnetic field acting on a stream of flowing fluid. When a conducting fluid moves in a magnetic field, the electric field set up depends on the intensity of the magnetic field, and the velocity of the fluid which depends on the flow rate

In an electromagnetic flow meter (Fig 1), the fluid itself must have some conductivity. The fluid then becomes a conductor with a length equivalent to the inside diameter of the meter. If a constant magnetic field is maintained and the induced cross voltage measured, then the velocity of the fluid (and so the flow rate) can be determined. (The directions of the fluid velocity, the magnetic field, and the induced voltage are given by Fleming's right hand rule and the corresponding magnitudes by Faraday's Laws.)

For the non-conducting fluids, the magneto-electric induction flow meter (where the magnetic field is induced instead of the electric field as in the electromagnetic device) has been devised. In it, a stationary electric field of very high strength is applied across the pipe. The electric field induces a magnetic dipole moment in the fluid which can then be measured. Since the induced magnetic field is proportional to the fluid velocity, this allows us to calculate the flow rate. However, very high voltages are required for induction.

Formato's meter combines the two concepts to change the flowing fluid's state of polarisation which depends, all other things being equal, on the velocity of the fluid. It works something like a parallel plate capacitor filled with water instead of air. Each water molecule acts like a small electric dipole aligned along the direction of the applied electric field (Fig. 2), but in such a way that the field between the plates is decreased, thus increasing the capacitance (over the value with air between the plates). The effect is distinct, though smaller, even for non-polar materials. In such materials, the positive and negative charge centres of the molecules are displaced just enough to form a small dipole.

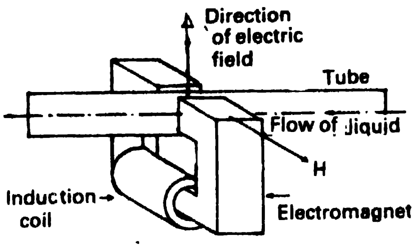


Fig. 1 The scheme of an electromagnetic flow meter. An electromagnet applies a strong magnetic field, which induces an electric field as shown. In a magneto-electric meter, the magnetic field is induced when an electric field is applied

If the water (or other fluid) in the capacitor is moving and is also subjected to a properly aligned magnetic field, it shows a different degree of polarisation. This change depends on the velocity of the water relative to the magnetic field; it turns up as a change in the material's effective dielectric constant which can be measured. This allows us to calculate the fluid velocity.

In electromagnetic flow meters the fluid must have some conductivity. The magnetoelectric flow meter is limited to extremely good insulators, and electric fields of the order of one million volts per metre may be required to induce appreciable magnetic fields (of even a few milligauss). Even a small quantity of conductive contaminants in the fluid can cause signal problems. The new polarisation flow meter can work with fields of less than a volt per metre to induce appreciable magnetic fields (of even a few hundred gauss). The new meter thus has a versatile range (even high conductivity of flowing fluids can be tolerated). Everything indicates that the new meter will cost less and be more reliable.

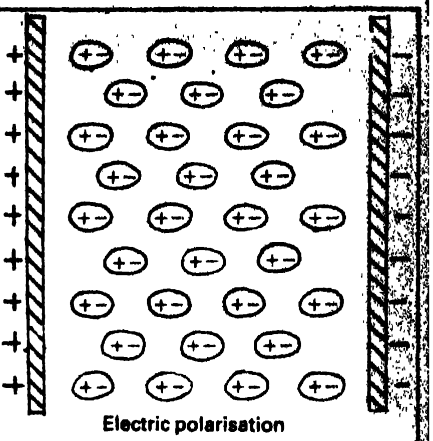


Fig. 2 Water molecules are polarised by an applied electric field. If a magnetic field is also applied, the polarisation changes according to the velocity of the fluid. This principle gives a flow meter of wider range covering both conductive and non-conductive fluids

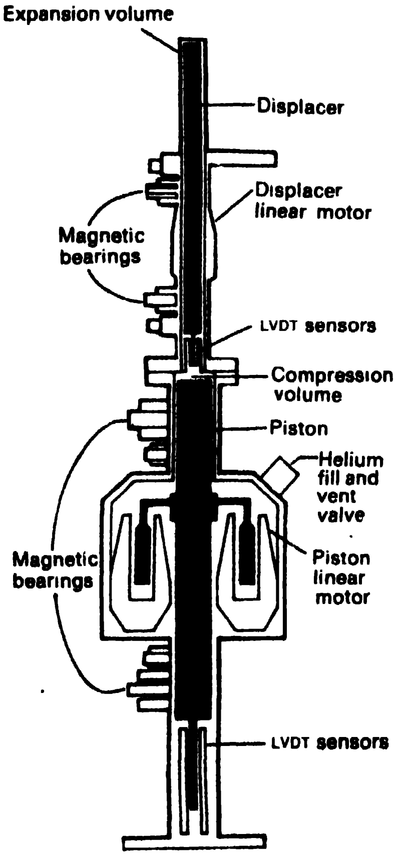
B. D. V.

Frictionless pumps for space applications

PISTONS and cylinders of pumps and compressors wear out because of friction at the points of mechanical contact. US National Aeronautics and Space Administration (NASA) engineers are now designing a refrigeration system for space application at the Goddard Space Flight Center, USA, in which piston and cylinder wear of reciprocating machinery will be at literally zero value (*Mechanical Engineering*, April 1981, p. 57).

In the NASA system—a Stirling cycle cooler—a piston (for compression) and displacer (for later expansion) are suspended in a magnetic field. An induced changing magnetic field drives the piston and displacer, so they need not touch the side walls or housing. Two linear motors—one for the compression and one for the expansion—and two sets of magnetic bearings are provided. The piston and displacer positions are monitored by linear variable differential transformer (LVDT) sensors and an electronic controller ensures a correct relationship between the compression stage and the expansion stage.

The system does away with complicated mechanical linkages and the friction involved, greatly reducing the strain on bearings and seals and simplifying their design. The NASA engineers estimate an increased equipment life from six months to five years—a six-fold increase and a significant achievement in space instrumentation. Of course, the system will be more costly, and will not replace common pumps. But the idea of using magnetic fields to minimise mechanical wear in reciprocating machinery will be an important innovation where system life is more important than cost.



Schematic view of the NASA frictionless pump. The pump uses helium for refrigeration in space applications. Helium enters into the lower compression end and is compressed into the small volume (see figure) Electronically controlled controlled magnetic fields surround both the piston and displacer and move them in the appropriate manner. Delicate sensors monitor piston and displacer motion and also their axial position to ensure correct positioning and timing. Friction is eliminated since there is no need for the piston and displacer to touch the sides of housing, ensuring increased instrument life

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ORDER IN RANDOMNESS

S. G. Dani

The order in randomness allows us to anticipate changes, evaluate policies, monitor quality and take corrective steps. But poor understanding and misapplication can land you into a mess

SO many phenomena in the world around us occur with remarkable consistency—apples detached from the trees fall to the ground, balloons go up, dry hay burns if lighted with a matchstick, milk splits if heated with a pinch of salt. Various laws of physics, chemistry and biology are also statements which spell out such a unique possible outcome under a given set of conditions.

On the other hand, there is another class of phenomena where the outcome is not so certain; it has many possibilities and they seem to occur randomly. A coin tossed into the air might fall either heads or tails up, a woman may deliver a boy or a girl, a card picked from a shuffled deck may or may not be the queen of hearts and a gadget you just bought may or may not work. What can we say of such 'chancy' events?

Of course, one may object; the multiplicity of possible outcomes is nothing intrinsic to the phenomena, but a consequence of the fact that the conditions are not adequately prescribed; for instance, the outcome of coin-tossing would be completely determined by the initial position of the coin, the angular momentum imparted to it, the atmospheric pressure, etc. But supposing that it is impossibly intricate to prescribe the conditions, or to know all the things which need to be known for a unique outcome, or even that such prescription is disallowed "in all fairness" (as in coin-tossing or card-picking)—we are still left with the question, is there then nothing that can be said about the whole business?

Even a schoolchild now knows that there is a method in the randomness of outcomes. Though the outcome of each instance may be arbitrary, the collective outcomes over a large number of independent instances show a definite pattern. Mathematicians working in probability, through centuries, have evolved elaborate theories to deal with randomness and its devious routes. The application of these theories can be a powerful analytical tool. But the simplicity of its underlying concepts is deceptive and there are many pitfalls on the road to their scientific application. Poor understanding and misapplication strengthen a growing popular suspicion that "statistics is a lie".

One's first acquaintance with probability is likely to dazzle one with the remarkable order in random events. Thus, for example, the proportion of male and female births remains remarkably consistent over several districts with similar social and environmental conditions. What is more remarkable is that significant departures for a particular set from an established proportion are almost always attributable to a 'cause' not presupposed in the data—and that is many times how theories grow and improve.

Pierre Simon Laplace (1749-1829) in his book *Essai Philosophique sur les Probabilities* describes one such episode. He analysed statistical data on the ratio of male births to all births for various parts of Europe and found the proportion to be around 22/43, but for Paris it was 25/49. To a layman the two figures are not particularly different. However, considering the very large size of the sample, Laplace estimated the possibility of an error and concluded that the discrepancy was unlikely to be without a cause. He found that the data for Paris also included foundlings — children abandoned from the surrounding countryside and lodged in children's homes in Paris. Among foundlings there were fewer boys than girls. Sure enough, the necessary corrections brought the Paris ratio close to 22/43 as expected.

For all its misapplication, knowledge of the orderly nature of randomness makes it possible to anticipate changes, take appropriate steps, and evaluate their effectiveness. Thus, over periods when the general conditions are similar, the birth and mortality rates are fairly consistent as borne out by the demographic data of various countries through the centuries. This alone can make it possible to gauge the population at a certain date in the future. And this will influence family planning targets, allocation of funds for education, housing and other medical and welfare facilities, the nature of transport needed, optimal schemes for life insurance and so many seemingly mundane things in our everyday life. It is again the laws that help us evaluate the success or failure of given policies. The success of family planning measures has to be indicated by a fall in birthrate of successive census figures and better living conditions or medical facilities by a drop in the mortality rate, while a thorough investigation into the causes would be called for by any *rise* in the mortality rate.

In our present age of mass production, the laws of "consistency in randomness" are about the only practical means we have of ensuring quality control of materials and efficiency tests of new products like drugs, etc. No manufacturer would be able to guarantee that *each* of his mass produced unit is free of defects. Yet, a higher proportion of defective units does mean a lower standard, and a lower standard cannot be shrugged off as a matter of chance, but would need investigation of underlying causes like substandard machinery or poor management. The same is true of impurities in foodstuffs, drugs, etc. Monitoring the *general* proportion of impurities and defects among the mass of products is the only way we can set standards of quality control.

Over the last three hundred years, probabilistic methods have developed considerably, and been applied fruitfully in the natural and social sciences. Unfortunately, the method has not come to be appreciated, or always correctly applied, outside a narrow circle of specialists. The somewhat complicated nature of the theory is only one of the reasons for this. The difficulty is also typified by the fact that the numerical values of probability associated with various outcomes cannot be handled too informally.

A working probabilist or statistician normally employs only a certain kind of arguments whose validity is borne out by the vast experience in the past; they are the basic hypotheses of the theory. Naturally, in deriving conclusions, every care has to be taken to use only those arguments consistent with the probabilistic method. But there are a certain kind of arguments, which we intuitively feel are "obviously" right and which are quite valid in the usual deterministic set up, but which break down in a probabilistic framework. An amateur who is apt to take a free-style approach, therefore, ends up in a mess.

Let us have a look at some of the simplest things that go into the method of probability. Suppose that there is a set of conditions under which $A_1, A_2, \ldots, A_n$ are all the possible outcomes. Suppose also that a large number of independent trials under the given conditions yields almost constant proportions. What this means is that the average number of times a particular outcome has occurred moves closer and closer to a definite number as we increase the number of trials. This may be verified by observing the sequences of averages or by plotting graphs, etc. We can then associate each outcome with a certain idealised value of the relative frequency with which the outcome occurs.

Of course, the idealised value may never be realised as the exact observed relative frequency over any number of trials; the observed values only approach the idealised values. This idealised value is then called the *statistical probability* (different from the a priori probability as we shall see later) of that outcome. When there is such a regularity in the outcome, we are compelled to suppose that there are objective laws about the outcome independent of the observer. The statistical probability is then a number as meaningfully associated with the outcome as, say, the density or specific heat of a substance. A change in the underlying conditions might doubtless change the statistical probability of an outcome; but so can the density or specific heat of a substance.

It should be borne in mind that since the actual trials are always a limited number, the computed value is likely to involve some error. Intrinsically, this is not anything special to statistics; all measurements involve some error such as rounding-off errors. However, in statistics there is also a component of the error arising from the possible discrepancy between idealised and observed relative frequencies.

Procedures have been derived to estimate the error in the actual computation of the statistical probability of an outcome. One of the first things we have to make sure is that the order of error involved is smaller than the difference in the probabilities of the outcomes being compared. Another thing to be remembered is that statistical findings from any experiment need to be treated as a whole. Comparisons of conclusions from two findings, even when they seem to agree, are untenable unless the two statistical findings are consistent as a whole. We will take a striking example of how too informal a handling in this respect can land you into a paradox. The particular example which we shall discuss below in some detail is a variation of the paradox known as Simpson's paradox.

Let us take the hypothetical case of a survey whose anticipated results have become an issue of hot contention. Two teams, A and B, are carrying out a survey in adjacent regions to find out whether the probability of a man being gainfully employed is more than that of a woman.

Team A first reports its finding. Out of 1,200 men and 800 women covered by their sample, 528 men and 320 women are gainfully employed (a grim picture perhaps, but any resemblance to existing situations is purely accidental!). The probability of a man being gainfully employed is 528/1200 = 0.44 and correspondingly for a woman, 320/800 = 0.40. The feminists are jubilant.

From the adjacent region team B now returns and reports its findings. Of the 1,000 men and 1,500 women in their sample, 670 men and 960 women are gainfully employed. The probability of a man being gainfully employed is 670/1000 = 0.67 and correspondingly for a woman, 960/1,500 = 0.64. The feminists have won their case.

But wait a second! There is the other person from the opposite camp. He has stood up and is waving his sheet of paper. He has simply added the results of the two teams. Of a total of 2,200 men and 2,300 women, 1,198 and 1,280, respectively were gainfully employed. And the probabilities work out to be 0 5445 and 0.5565 for the men and women respectively—pretty close but with the *women* having a lead. The same data have been used and opposite conclusions reached. If now anyone tells you that statistics is a lie, you may indeed agree, "it's worse".

There is really no room for such cynicism. If things seem so confusing, it is because you are looking (or have been made to look) at them from a wrong angle. Let us begin to untangle the mess. Firstly, in making any comparison of the above kind, we implicitly assume that there is no fundamental qualitative difference in the nature of the two surveys. After all, if things were really different, there would be no absurdity. It would then be simply like saying that tea is good, ice-cream is good, but their mixture is no good.

In practice, such assumptions, have to be substantiated by ensuring that the regions (and samples) under survey are comparable in terms of the socio-economic, political, cultural and other factors which may influence the probability of gainful employment. Looking at the above figures, a seasoned probabilist would tell you that this has not been carried out adequately and that there must be certain missing factors causing what he claims to be a significant difference in the findings of the two surveys, when each is viewed in its entirety.

Let us, however, ignore him for the time being. After all, it can be argued, if both teams have found the probability of gainful employment to be greater for men, where is the difference? So let us proceed on the assumption that there is no fundamental difference between the regions and that it should in principle make no difference whether we get our data from either of them.

Recall now that the probability of gainful employment for men according to the data of team A is 0.44 and from the data of team B, 0.67. How do we explain this difference? If the regions are similar, then we are forced to the conclusion that this is due to certain errors (perhaps random), so that the degree of error would be as large as 0.67−0.44=0.23 for men, and on similar lines 0.64−0.40=0.24 for women. All in all, the findings of the two teams then indicate that the probability for men lies somewhere between 0.44 and 0.67, and for women between o.40 and 0.64.

There is thus no contradiction in the two results. The degree of error is much larger than the difference between the two values to be compared (0.44−0.40=0.04 for team A and 0.67−0.64=0.03 for team B). Such estimates could be good enough from certain aspects of economic planning, but definitely not for comparison between the two probabilities. If the regions are to be similar, then taken at face value, the findings together make no case either for or against the feminists.

We should remember, however, that we had been forced to this conclusion on the assumption that the two regions are similar. Theoretically, this is still possible, but it would be extremely rare in practice. The sizes of the samples in our hypothetical examples are quite large, so the statistical error would be of a much lower order than what we have encountered above. What therefore remains would have to be attributed to mechanical errors — choice of instruments or procedure. Normally, enough precautions are taken in this respect. Finally, therefore, we would have to go back to the probabilist's suggestion that the findings show the two regions to be fundamentally different and look for the underlying causes of the different values.

There is an interesting characteristic of our data which makes the paradox possible. To spot it, try making up your own data for the hypothetical case, only with the following constraint. If m_1 and m_2 are the two estimates of the probability of gainful employment for men, with w_1 and w_2 being the corresponding values for women, then there must be no number which is *both* between m_1 and m_2 and between w_1 and w_2. In other words, the intervals between the men's probability values and the women's probability values should not overlap. Try as you will, you will not get paradoxical findings. This constraint means that the error involved is small enough for *comparisons* not to go awry.

It should be evident by this time that the task of determining the statistical probability would be simplified greatly if we had some way of anticipating what this value may be. In practice, such a notion may be developed from considerations of symmetry intrinsic to the phenomenon. For instance, one anticipates the probability of throwing a six with a homogeneous cubical gambling dice with six faces as 1/6, because all six faces being indentical, throwing any one number is equallv probable. Such a notion was first systematically developed as a guide to gamblers advising them of the profitability of one bet against another.

The notion of probability thus developed is called the 'classical' or 'a priori' notion of probability. It involves a certain identity or symmetry among all the possible 'elementary' outcomes. The probability of each elementary outcome is then taken as the reciprocal of the total number of elementary outcomes. A combination of elementary outcomes is called an event. The

Mapping randomness

THE randomness of a physical phenomenon does not mean that the phenomenon is not governed by any rule. It only means that the underlying rule is such that when we try to gauge the phenomenon in terms of the occurrence, or non-occurrence, of finitely many outcomes at constant intervals of time, it shows randomness. And this gives rise to a question currently being hotly pursued in a branch of pure mathematics called ergodic theory—which are the underlying rules of movement which exhibit randomness? The answer is far from being satisfactorily known.

To go into the question we shall set up something like a game. The game is played on a surface of finite area—say, a torus (the shape of the surface of a doughnut or a *meduvada*). For simplicity, assume that the total area is one unit. We now prescribe where each point on the torus will move in unit time. We call the later point the successor of the earlier one. Our rule shall be such that each point on the torus is the successor of one and only one point on the torus. On the surface of the torus is also drawn a map, which divides the torus into countries, $A_1, A_2, \ldots, A_k$. The game now proceeds—it is a game of eternal musical chairs with no extra people or extra chairs, played by the points on the torus, each point proceeding to its successor point.

Let us say that the transformation (or our prescription for the game of musical chairs) exhibits eternal randomness with respect to the map if the following happens. The area of the set of all points in a country A that have their successors in a country B (not excluding the case where B is the same as A) is proportional to the area of B.

We have also the map. We call a map adequate if the following happens. No two points (except those belonging to a certain negligible set, which we leave out of consideration here) shall follow the same course of history (and future) as far the property of belonging to the countries of the map is concerned.

And here finally is the hotly pursued question—which are the transformations that exhibit eternal randomness with respect to some adequate map? (Such transformations are said to be isomorphic to Bernoulli shifts.) Intuitively, what does the question mean? Suppose we are watching a phenomenon taking place on the surface. The transformation gives the net change in it in unit time. Intuitively, when would it seem as if the choice of the country for the successor is random and is the randomness of the choice completely determined by the relative areas of the countries? And which are the underlying rules when such a thing happens?

Some way to the answer was cleared by R. L. Adler and B. Weiss;in 1970 they proved that a certain class of transformations which preserve certain 'multiplications' on the torus are Bernoulli shifts. A similar result for higher dimensional analogues of the above torus was later proved by Y. Katznelson. For various other classes of transformation, however, the question is still open.

Interestingly, it has now been shown that the motion of two particles in a box which keep moving like the gas molecules intermittently colliding with each other defines a transformation of the above kind, one that is isomorphic to a Bernoulli shift.

Can we relate this notion of randomness of a transformation to, say, the randomness of coin-tossing outcomes? Consider a case like the above in which the map consists only of two countries with an equal area. Now imagine that for every point we have made print-outs showing which of the countries it belonged to in its entire history and also in the future. If the transformation is isomorphic to a Bernoulli shift we would find that these print-outs would match in a natural way with the print-outs of coin-tossing trials carried out indefinitely—the only thing we have to do is to call one country Heads-up and the other Tails-up! Viewed in another way, then, points of the torus correspond to complete print-outs of coin-tossing trials.

The question of a comparison of such print-outs, expectedly, arises also in coding theories, like those used in communications (SCIENCE TODAY, July 1980, p. 16). When the print-outs of two systems (whether on a torus or more generally) match with each other with respect to some suitable adequate maps, as in the above example, the systems are said to be isomorphic. In various problems in coding theory it is important to know whether two given systems are isomorphic or not. A fundamental theorem proved by D. S. Ornstein in 1970 says that two Bernoulli shifts are isomorphic if and only if they have the same 'entropy', the 'entropy' being a measure of their randomness. (For our kind of transformation isomorphic to a Bernoulli shift relative to a map with n countries of equal area, the entropy would be log (n); generally, if the areas of the countries are $a_1, a_2, \ldots, a_n$, with the total area equal to one unit then the entropy is the sum of $a_1 \log(1/a_1)$, $a_2 \log(1/a_2)$, etc.) A profound result, which ties up isomorphism with equal randomness!

S. G. D.

probability of an event is the sum of possibilities of outcomes constituting the event. The probability of the event of drawing an ace from a shuffled deck, is made up of four possible elementary outcomes (since there are four aces) and the probability of the event is 1/52 + 1/52 + 1/52 + 1/52 = 1/13. Similarly that of picking a red card is 1/2.

Once we have this notion, it can be extended in a natural way to the outcomes of finite number of repeated trials of the same experiments. We assume however that the occurrence of any particular event in one of the trials is independent of the outcomes of any other trials. A possible outcome from the totality of trials is a collections of outcomes of individual trials, one per trial. The probability of such an outcome is then the product of the probabilities of the constitutent outcomes of individual trials. Thus the probability of drawing an ace from a shuffled pack, putting it back, reshuffling and then drawing a red card is 1/13 x 1/2 = 1/26.

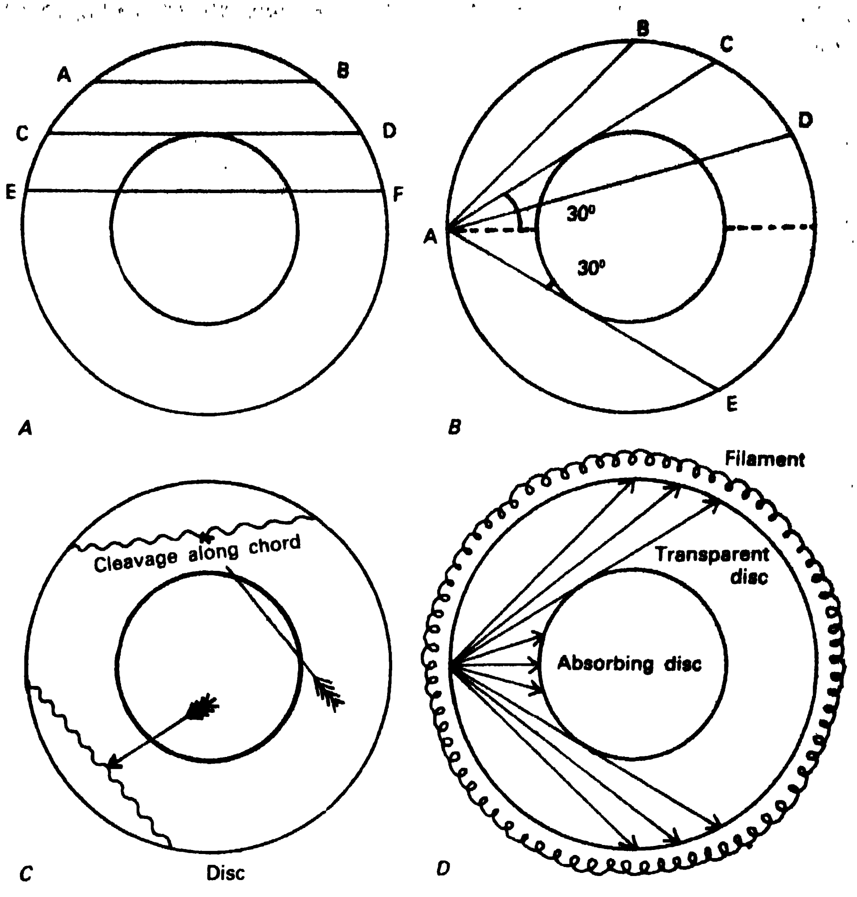
Sometimes the number of possible outcomes is infinite, for example, the possible direction in which a gas molecule will travel, or the point on Earth which would be just below the Skylab's centre of gravity when it hits the Earth. The probability of any one precise outcome (the gas molecule travelling exactly north, or the Skylab hitting the Earth with its centre of gravity exactly over the tip of the TV tower in Bombay, etc) is zero. In such a case, however, if we choose suitably large events (combinations of elementary outcomes which will also now be infinite), then numerical values of probability can still be assigned meaningfully to such events. Thus, there will be a definite, non-zero probability of the gas molecule travelling within 5 degrees off north, or the Skylab falling in India. In the former case symmetry considerations will show that the probability is 10/360 = 1/36.

So far, so good. But here again, there are pitfalls. Very often, there is an obvious natural choice for symmetry considerations, but this is in no sense automatic or final. As an illustration we will take another example in a little detail. Suppose we pick at random a chord of a circle with unit radius. What is the probability that the midpoint of the chord is at a distance of at the most ½ unit?

Let us try reasoning it out. The event takes place only if the midpoint of the chord falls on the inner disc of a half-unit radius around the centre of the circle. This disc with a half-unit radius has an area that is one-quarter of that of the disc of unit radius formed by the original circle. Since the latter disc is where the midpoints of *all* the possible chords can lie and the smaller disc is where our event occurs, the probability in question should be 1/4.

We can, however, reason in another way, too. A chord has its midpoint as a distance of at the most half-unit, when its angle with the diameter through one of its end points is less than or equal to 30 degrees (see figure). Since, in general (for all possible outcomes), the angle can be anywhere between 0 and 90 degrees, the probability of our event now turns out to be 30/90 = 1/3. Two different values for the probability of the same event!

Again, it is not that one of them is incorrect. What it means is that the symmetry considerations employed are incompatible with each other. There is no intrinsic reason for one of them to be better than the other. Indeed, translated into a physical situation any one of them may turn out to be a better measure than the other, depending on the situation.



Different symmetry considerations may give different probabilities for the same event. Yet each may be suitable to different physical situations. The probability of a chord in a unit circle having its midpoint at a distance of at most half a unit is 1/4, as in *A*, but 1/3 as in *B*, depending on the consideration (see text). The former value is valid if we are shooting arrows randomly at a disc which breaks along a chord with the point of impact as its midpoint and we want that at least some part on the inner disc be broken *(C)*. The latter is valid if the unit circle is a transparent disc with an absorbing disc of half unit radius at its heart and we want to estimate how much radiation from a filament surrounding the larger disc is absorbed by the smaller disc *(D)*

Suppose that we have a disc of unit radius made of brittle material. It breaks along the chord with the point of impact as its midpoint. Now we set up the disc at a distance and shoot arrows at it. What is the probability that the chord along which it breaks belongs to the event that we considered above? In this case the pertinent value of probability is our earlier one, 1/4.

Let us now take another situation. The outer unit circle represents a circular filament of radiating material radiating uniformly in all directions in the plane of the circle. (For simplicity, suppose the radiation is restricted to the plane of the circle.) A disc of half-unit radius, made of material that absorbs all radiation falling on it, is placed at the centre. The directions of radiation passing through the disc of unit radius encircled by the filament determine chords to the circle. The subset of chords given in the problems corresponds to the radiation absorbed by the absorbing disc of half-unit radius

We leave it to the reader to convince himself that the proportion of the radiation absorbed by the smaller disc to what it would be for a similar disc of unit radius, is 1/3. Thus in this case it is the other value of probability which is more pertinent.

The moral of the above discussion is that the notion of randomness or symmetry does not come pre-packed with the mathematical model of a problem. It has to be superimposed on the model employing considerations of symmetry for the problem at hand, which often might not have anything to do with the mathematical model itself. Nor should the reader believe that this is so only when the number of possible outcomes is infinite, as in our example. The following example, of great importance in physics, will show that it can happen even with finite outcomes.

You have n balls to be put randomly into N boxes (where N is larger than n). What is the probability that no box contains more than one ball? Let us take a simple case of 2 balls to be put into 3 boxes. Common sense reasoning would tell you that there are 9 ways of putting 2 balls into 3 boxes. If each box is to contain at the most one ball, exactly one box has to be empty and there are three possibilities for the empty box. Also with each possible choice of the empty box, there are two ways in which we can put the two balls in the two remaining boxes. So 6 out of the 9 different ways of putting the balls into the boxes satisfy our criterion; the probability we are looking for is 6/9 = 2/3.

This is the answer for ordinary balls which can be told from each other (say by sticking labels on them). It turns out that if we have photons or nuclei instead of the balls and the possible 'microscopic states' as the boxes, the answer is different. According to the Bose-Einstein statistics, photons (as also certain other particles) behave as if you could never distinguish between them! If we cannot distinguish which ball is which then there are only 6 (instead of nine) distinguishable ways of putting the 2 balls into 3 boxes. Bose-Einstein statistics then works on the assumption that these 6 (not nine) ways are equally probable. Of these,3 will satisfy our conditions (once we choose the empty box, we cannot have two ways of filling 2 balls in the other 2 boxes, so the probability will be 3/6 = 1/2.

As Bose-Einstein statistics explains certain phenomena which cannot be otherwise explained, the symmetry condition is vindicated. A similar non-intuitive symmetry consideration arises in the Fermi-Dirac statistics. In general, mathematical theory offers the scientist a choice of various randomness formulations; it is up to him to make the proper choice.

Apparently, we have here two notions of probability, the one derived from symmetry considerations (the a priori notion) and the one derived by testing outcomes (the statistical notion). There is a subtle but definite difference between the a priori and statistical notions of probability. And the difference has fuelled an ongoing philosophical debate. However, Rudolf Carnap, who was one of the pioneers setting the logical foundations of probability, asserts that though the notions are certainly different, there is no contradiction or incompatibility between them. He argues that much of the argument among conflicting philosophical schools stems from the different contexts to which they apply the notions.

Philosophical questions notwithstanding, there is a lot of evidence to advance the hypothesis that the two notions are equivalent in practice. Good coins, well-chosen as far as uniformity is concerned, have been painstakingly tossed to verify to a great degree of accuracy that the statistical probabilities of the king and tail event are equal to their a priori values of 1/2 each. Similar verifications are also carried out in the case of various experiments for which the notion of classical probability exists—for example, drawing coloured balls from a bowl, etc.

Imagine a huge super-bowl containing a very large number of white and red balls, otherwise identical. Suppose we want to find out the proportion of white balls. There are too many balls for it to be practicable to count all and calculate the proportion. We may then try to draw out a ball at random and note if it is red or white. We may then make a number of trials, as large as practicable, say 1000, in a number of subsets, of say 100 trials each. Suppose we then find that in each of the subsets of trials the proportion of white balls is close to a definite number, say 3/4. Note that this is what the ratio would be, as has been painstakingly verified, if we knew the composition to be three white balls to one red. We therefore conclude that the proportion of white-balls in the bowl is 3/4. Among other things, this involves the hypothesis of the equality of a priori and statistical probabilities.

A second, and very potent, test of the hypothesis of equivalence lies in the experimental verification of the various laws of physics whose deduction is motivated by the considerations of the equivalence of the two notions of probability. Various laws of the behaviour of gases which assume the kind of notion of probability for a moving gas molecule mentioned earlier have been found to be successful. Similar considerations go into many of the laws of physics, chemistry, astronomy, etc. Sometimes, the symmetry condition (or the model of a priori randomness) has had to be changed. But the revised notions have been successfully treated as intrinsic to the phenomena under investigation. Indeed, the hypothesis is so entrenched that a working physicist or statistician seldom finds it necessary to distinguish between the two notions.

The mathematically minded reader now faces the following most interesting question; could one prove the hypothesis mathematically? This is almost the case—but not quite. Indeed, sometimes the so-called laws of large numbers, of which we discuss a simple variant below, are taken to be the proof.

Let us confine ourselves to coin-tossing. We have only two possible elementary outcomes with equal a priori probabilities of 1/2 each. There are then 2^n possible outcomes in a series of n throws. Let us now agree on a level of accuracy up to which we wish to compare the a priori and statistical probabilities for the case at hand, say a level of accuracy of $1/10^m$ (the *mth* decimal place). Let an n-tuple (a given-series of results of n trials) be said to be 'good' if the proportion of king-events in the n-tuple differs from 1/2 by not more than $1/10^m$. An n-tuple is said to be 'bad' if it is not 'good'. One form of the law of large numbers then asserts that for any given m, for a sufficiently large number n of the trials the proportion of 'bad' n-tuples becomes less than $1/10^m$.

Of course, no matter how large we make n, there may still be 'bad' n-tuples. So the law of large numbers above does not quite prove the hypothesis. However, since the proportion of 'bad' n-tuples itself keeps shrinking indefinitely it does make the hypothesis more convincing and acceptable. And, of course, it allows us, based on the hypothesis, to deal with so many situations of our age, which has brought probabilistic laws into everything; from the tiniest particles to the distribution of stars, and from mass production to mass behaviour.

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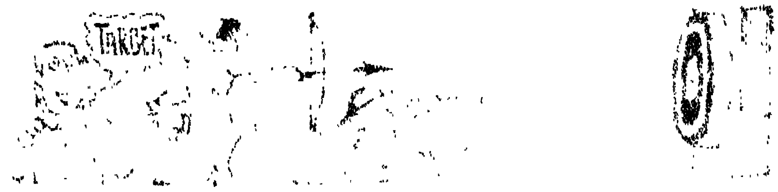
How SCIENTIFIC is your LANGUAGE?



The language of the scientist is precise. In daily life we interchange a numbers of words and expressions. Often, these may mean quite different things in science. Answers to the 12 questions here are given on the next page.

1. A clever trader buys goods at the equator and sells them at the poles at the same rate per kilogram as his cost price. If he is to make profit without cheating, should he deal with *mass* or *weight*?

2. Two students surveyed the economic status of a neighbourhood. One student (A) arrived at the conclusion that the yearly *average* income was Rs. 2,500 per family there, while the other (B) maintained that the *mean* income was Rs. 10,000 per family per year. They consulted a statistician who gave them the correct information. Who do you think was correct, A or B?

3. An environment-conscious scientist thinks that the pollutants of chemical factories in the Chembur area of Bombay are influencing the survival of the trees in the area. If you *had* to substitute "influencing" in the last sentence, would you say the pollutants are (A) "*affecting* the survival" or (B) "*effecting* the survival"?

4. The accident at the Three Mile Island nuclear power station in Pennsylvania, USA, shows that such accidents are possible. It may appear contradictory when nuclear scientists all over the world maintain that such disastrous accidents are highly improbable. Are they right? Yes or No.

5. Dr. Raj has two good balances in his laboratory. Balance A can weigh down to a milligram while balance B weighs down to a tenth of a milligram. A scientist living next door claims that balance B is more sensitive, but Dr. Raj argues that it need not be so, since they have not determined the *sensitivity*. Dr. Raj's only claim is that the detectability of balance B is higher than that of balance A. Is Dr. Raj correct? Yes or No.

6. A doctor you know claims that *liquids* and *fluids* are the same, and when asked why blood is not called a liquid, he says it is just scientific tradition. Is he right or wrong?

7. On your way to the hospital you meet an old friend who says that he is also going to the hospital, to "collect his autopsy report". Is he right or wrong?

8. The other day at the railway crossing we saw two trains crossing each other at the same *speed*. Were they certainly at same *velocity* also? Yes or No.

9. If things are missing, a housewife has a knack of saying that they simply "evaporated into thin air". The other day she left a piece of camphor on the table and, later, when she did not find it, she said in her characteristic manner that it "must have evaporated away". Her husband said, "Oh, dear, it has ________!" (Fill in the blank evaporated/sublimated.)

10. When you paint an earthen pot with some dye, does the dye get *absorbed* or *adsorbed*?

11. A couple (having no children yet) was celebrating their first wedding anniversary with a cake. The wife who always wished to share everything equally with her statistician husband asked him to divide the cake in a 1:1 *ratio*. The husband said that it was not possible. Was he right or wrong?

I'LL TAKE THE BETTER HALF

12. A man felt very depressed when the doctor told him that his four-year old son was suffering from congenital heart disease. He argued with the doctor that none of his or his wife's ancestors were known to have suffered from the disease, and so wanted the doctor to examine his son again. However, the doctor maintained that the diagnosis was correct. Are *congenital* disorders the same as *hereditary* disorders? Yes or No.

Next Month: a Preview

Thermoluminescence

Thermoluminescence has found several applications in archaeology, geology and forensic science.

Helmets

Ride bareheaded—and doom is round the corner

On to the cosmic merry-go-round again

The stars, the galaxies and the universe all spin round and round in their journey through space

Glaciers

How do these rivers of ice flow?

Trees as dust filters

Green trees can effectively shield cities from dust

Rubik's cube

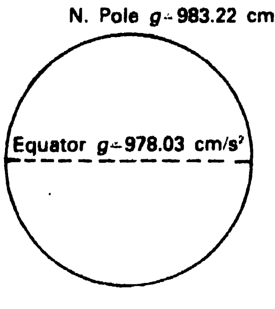
A colourful cube originating in Hungary and Japan is the cause of a new disease "Don't-touch-itis"

Nobel Prize winners, 1981

SCIENCE TODAY
December 1981

The Answers

1.—Weight: The weight of a substance is equal to the product of its mass and the acceleration due to gravity. W = m × g. Since the value of g is higher at the poles than at the equator, the trader is giving away less mass for the same weight. In this case the trader must be using a spring balance. Any other balance where counter weights are used would record mass and not weight.


N. Pole $g \simeq 983.22$ cm/s^2
Equator $g \simeq 978.03$ cm/s^2

Earth, showing approximate values of *g* at the equator and pole

2.—Both A and B are correct: The first student uses the word average to refer to the mode. The mode is the maximum frequent class. The second student uses the mean which is a precise term representing the total of the incomes divided by the number of families studied. The word average is a loose one in that it represents the mean, mode, median and also geometric mean, root mean square, etc. So, when one says average one is telling very little unless he specifies which average he is referring to. This is not the case in biological variables where the mean, mode and median tend to be the same (normal distribution).

3.—A: The pollutants are affecting the trees. It is the effect of pollutants on the trees which the scientist is studying

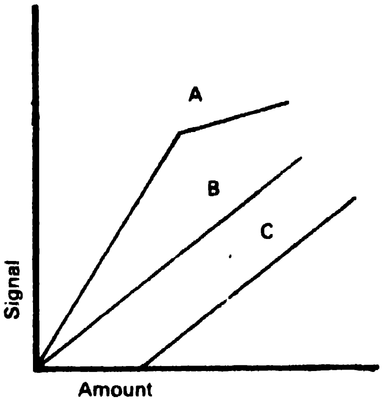
Mohan

Right: **Residents of Chembur, Bombay, remember the time, not long ago, when this tree bore fruit**

4.—Yes: Possibility implies a qualitative statement, whereas probability is a quantitative one. An event is said to be possible even if it can occur with an extremely low probability. In the above example, such accidents are possible in future but the probability of such an accident is less than one in a million per year.

Three Mile Island mother protecting baby

5.—Yes: Detectability, or the limit of detection, is the smallest amount that can be detected. Sensitivity is the change in signal that is produced by a certain change in another magnitude. Sensitivity **can vary along the scale and the word sensitivity is often used (rather, misused) to mean "the limit of detection". In the given figure, B and C have the same sensitivity (slope) but different limits of detection (intercept). A and B have the same limit of detection, but differ in their sensitivities. In A itself sensitivity changes along the scale.**



Sensitivity and the limits of detection

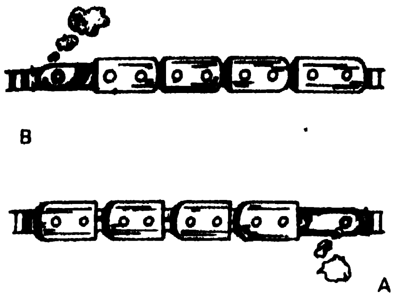
6.—Wrong: A liquid is a state of matter intermediate between a solid and a gas. Fluid by definition means any substance which can flow. This definition includes homogeneous mixtures of solids in liquid (blood) or in a gas (smoke) apart from pure liquids and pure gases.

7.—Wrong: Autopsy is performed on dead bodies (post-mortem operation) to ascertain the cause of death. Biopsy is performed on the tissue obtained from a living individual to ascertain the cause of a disease. Obviously, your friend was going to collect his biopsy report.

"I'm *not* mistaken. It's my autopsy report I want!"

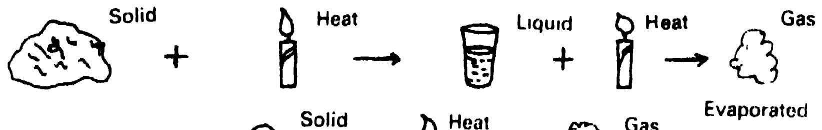
8.—No: Speed refers to only the rate at which a distance is covered without any regard for direction, whereas velocity includes both speed and direction. In the above example, if the speed of the trains was X, then the velocities of the two

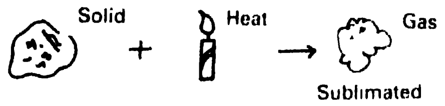
trains were X and —X, while the speed remained the same, X.



Train A has a speed of 60 kmph and velocity +60 kmph, while train B travelling at the same speed has a velocity —60 kmph

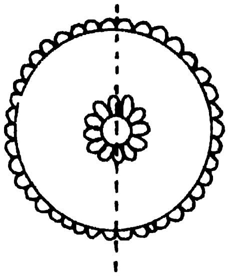
9.—Sublimated: Sublimation is defined as a conversion of solid to gaseous state without becoming a liquid. Evaporation, on the other hand, is the conversion of a liquid into a gas. In this case, solid camphor must have got converted into vapour (sublimated).



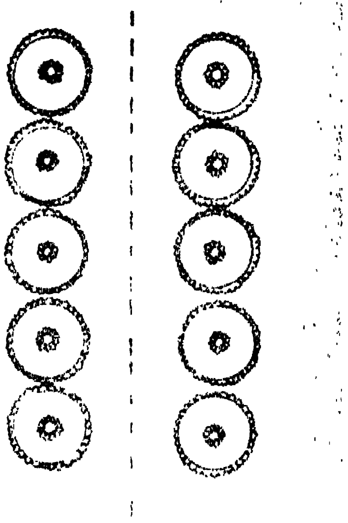


10.—Adsorbed: Adsorption is a property of a solid (adsorbent) holding molecules at its surface. On the other hand, absorption is the penetration of one substance into another.

11.—Right: Ratio is the integral relationship between one or more things while proportion represents a fraction of a unit. In this case the distribution can be done in a 1:1 ratio if there were two cakes. Since there was only one cake it can only be distributed in 0.5:0.5 proportion.



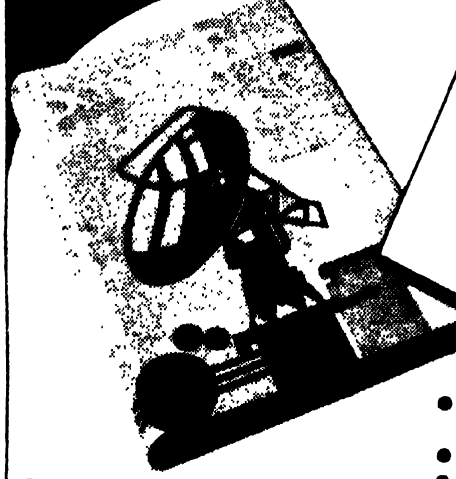
One cake can be shared by two people in a 0.5:0.5 (or 50 per cent - 50 per cent) proportion, and they get half a cake each



If 10 cakes are shared among two people in a 1:1 ratio, they get five cakes each

12.—No: The doctor was right. Congenital diseases are those present at birth. This term refers usually to non-hereditary disorders Hereditary diseases are those transmitted from parents to offspring.

This quiz was prepared by I. NARAYANA RAO, T. GOPALAKRISHNA and R MITRA of the Biology and Agriculture Division, Bhabha Atomic Research Centre, Bombay.



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BOOKS

Reviving inorganic chemistry

Theoretical Principles of Inorganic Chemistry by G.S. Manku, Tata-McGraw-Hill, New Delhi, 1981, 564 pp, Rs. 28.50.

THE spectacular progress made in the various branches of chemistry during the last two decades makes it difficult to draw any lines of demarcation between inorganic, physical, analytical and organic chemistry. Further, the manner in which chemistry is taught today in western countries (as with a few centres in India) has so substantially changed that it is impossible to distinguish between the so-called inorganic chemistry and the present-day structural chemistry.

Inorganic chemistry attained a rather bad reputation in our country because of the manner in which it was taught, the stress having been on memory rather than on principles underlying certain phenomena. The few attempts made by certain universities to teach the subject in terms of structure and its correlations of chemical properties, however, suffered for want of the right type of books by Indian authors. *Theoretical Principles of Inorganic Chemistry* fills the gap admirably.

Prof. Manku's book would be very useful for graduate students majoring in chemistry. Of the 13 chapters, the first two describe the structure of atoms, covering a requisite quantum of classical mechanics and quantum theory. The much neglected field of periodic classification has been carefully covered in the third chapter. Instead of a discussion of groups and periods in the usual way, the author has vividly discussed important variable parameters, such as variation in nuclear charge, atomic volume, ionic radii, ionisation potential, electron affinity, and electro-negativity.

The next two chapters concern the nature of chemical bonding. The author has very lucidly explained the bond formation in terms of various theories of metal-ligand bonding. Important aspects like lattice energy, Born-Haber cycle, etc are well considered.

The subsequent chapters pertain to acid bases, redox system and solvents. The protonic acid-base concept and acids and bases are well explained. The most important bases of half reaction and standard electrode potential are very neatly covered in the chapter on redox system. The chapter dealing with isolation of elements is somewhat classical and with the rhetorical descriptions of various methods of purification of metals, the subject matter turns out to be rather disinteresting. The last three chapters are fully devoted to co-ordination chemistry, which, one might say, constitutes the backbone of modern inorganic chemistry. The concept of stereochemistry, the theory of co-ordinate bond, covering valency bond theory, crystal field-theory, molecular orbital theory and ligand field theory are well depicted with appropriate illustrations. The final chapter on properties of co-ordination compounds adequately touches the area of spectral characteristics, thermodynamic stability of complexes, magnetic properties and inorganic reaction mechanism.

Every chapter concludes with some questions which, by and large, are conventional. It would have been most rewarding if a few quiz-type questions to test the fundamentals were also included. Similarly, numerical problems are very limited. Notwithstanding the few errors, the author has done an admirable job. One now looks forward to the proposed second volume covering the chemistry of transition and non-transition elements.

S. M. KHOPKAR

Dr. Khopkar is Professor of Chemistry at the Analytical Chemistry Laboratory, Indian Institute of Technology, Bombay.

BRAIN TEASERS

Six Statements

HERE is a set of six statements, only one of which is correct. Which one is correct?

1. Only one of these statements is not correct.
2. Only two of these statements are not correct.
3. Only three of these statements are not correct.
4. Only four of these statements are not correct.
5. Only five of these statements are not correct.
6. Only six of these statements are not correct.

P. RAGHU KUMAR

(Solution next month)

Solution to last month's Brain Teaser

Daughter's age

Let the daughter's age be $10x + y$, where x and y are digits. Then the mother's age is $10y + x$.

Also, $10y + x + 5 = 2(10x + y + 5)$

Simplifying, $y = \frac{5 + 19x}{8}$

The minimum value of x is 1, and hence $y = 3$. For higher values of x, y is not a digit. Hence, the daughter's age is 13.

"Let me make it clear–you will work here only till our brick hardness tester comes back from repairs."

All about leucoderma

Abburi Ramaiah

Intisar Hussain

Why the skin starts losing colour is yet an unsolved mystery

WHEN the geometry lesson got boring, fourteen-year-old Nicholas found himself a more interesting thing to do. Picking up his dividers, he scratched out the name of his pretty classmate, Mandy, on his right forearm. For a couple of days after that he sported the crusty scratch marks and then probably he forgot about it. Four months later he was in for a rude shock: "MANDY" began to reappear in white on his forearm like an old film sent for developing. And together with that, he noticed, white patches began appearing on his knees, skin, elbows, eyelashes and chin. Nine months later there were more patches of discolouration on his trunk and face, some of the old patches had enlarged but, quite embarrassingly, the name etched on his arm remained unchanged. His ailment is known as vitiligo.

In laymen's terms, this cosmetically disfiguring disease is known as leucoderma. Leucoderma is a generic term for lightened skin; it includes vitiligo and there is no fundamental distinction. Also, to laymen, vitiligo is a less scary term than leucoderma. It is a common experience of dermatologists that most people get alarmed when they notice white patches, that they have leucoderma. When told they have vitiligo, however, they seem to relax.

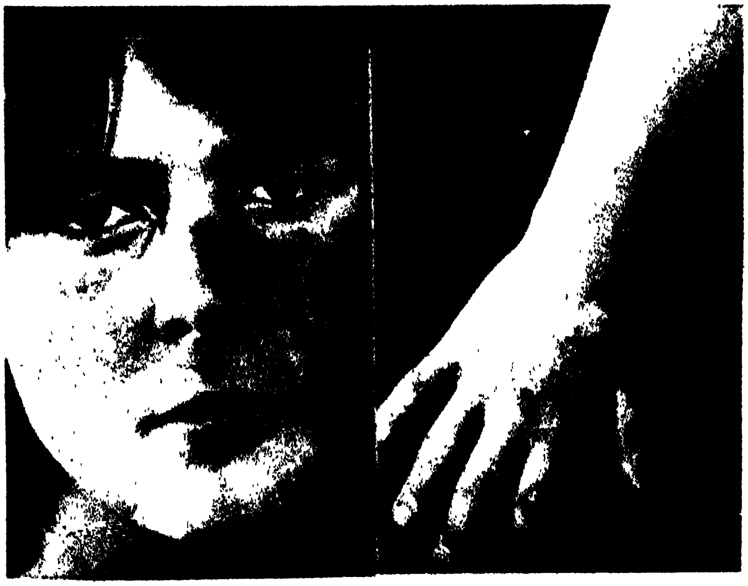
Vitiligo has no racial barrier; only, it is more conspicuous in darker people. But for the lack of pigmentation in patches, the afflicted individuals are as normal as anyone else. The disorder, known for more than 4,000 years, is often confused with other skin depigmentation diseases. In the *Atharva Veda*, it is referred to as *shwetakusth*. *Kusth* in Sanskrit is a general term for all skin ailments and also for leprosy, and *shweta* means white; thus *shwetakusth* would mean white leprosy. Leprosy is caused by a microorganism; vitiligo is not caused by any organism and therefore it is not contagious.

In some parts of India, the disease is known as *pandurog* — the disease that King Pandu got his name from. *Pandu* could be taken to mean white or pale. It could have been that King Pandu was an albino. But strangely, in some north-eastern states, the name is used for jaundice.

The confusion is quite widespread. Some references to leprosy in the *Bible* may have actually been cases of vitiligo. For example, "May then the leprosy of Naman cleave unto thee, and unto thy seed forever, and the (Gehazi) went out from his (Elisha's) presence a leper as white as snow" (2 Kings 5-27); "...and the cloud departed from off the tabernacle, and behold, Miriam became leprous, white as snow" (Num. 12:10); ".... if the bright spot be white in the skin of the flesh, and in sight be not deeper than the skin, and the hair thereof be not turned white; then the priest shall shut up him that hath the plague seven days" (Lev, 13:4).

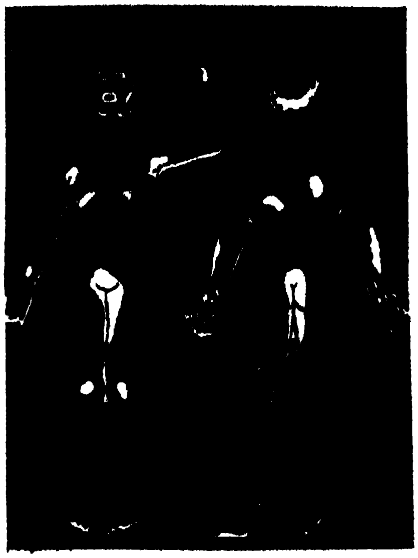
And in the New World "lepers" were sacrificed to the Goddess of white Maize. According to J. G. Frazer, these sacrificed ancient Mexicans may have been vitiligo-affected individuals. The small white spots could be taken to resemble corn kernels and thus the afflicted person's fate was sealed. The confusion persisted almost up to the present. In its 1956 edition, the *Shorter Oxford English Dictionary on Historical Principles* defined vitiligo as a species of leprosy.

The disease affects about one per cent of the world population and about three per cent of the Indians. It can occur at any age, right from childhood to senescence. It occurs equally in both sexes. It may develop as a single patch or as multiple patches. The patch(es) may remain static for a long time and then suddenly start progressing or may enlarge gradually. The patches may be sometimes symmetrically distributed. On the whole, the distribution of the depigmentation cannot be predicted. It generally starts in the skin around the orifices, for example, on the lips, around the eyes, etc.



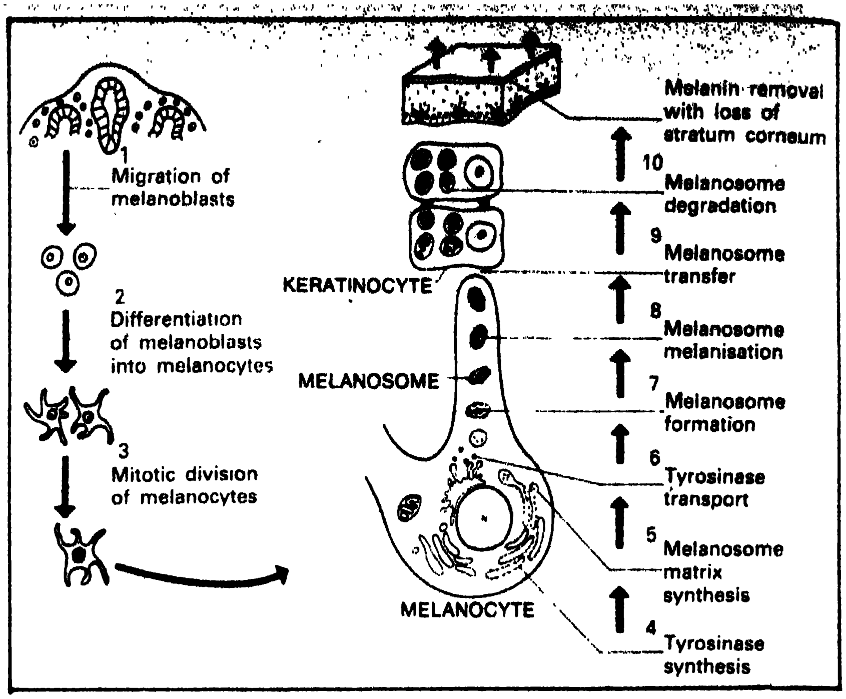
(R D Sweet British Journal of Dermatology)

Vitiligo as a result of trauma. This 14-year-old boy developed white discoloured patches four months after a self inflicted injury. He had etched out the name of a girl on his right arm with a pair of geometry dividers



Typical distribution of depigmentation patches of vitiligo involving areas of repeated local trauma

What causes vitiligo?


1
Migration of melanoblasts
2
Differentiation of melanoblasts into melanocytes
3
Mitotic division of melanocytes
KERATINOCYTE
MELANOSOME
MELANOCYTE
Melanin removal with loss of stratum corneum
10
Melanosome degradation
9
Melanosome transfer
8
Melanosome melanisation
7
Melanosome formation
6
Tyrosinase transport
5
Melanosome matrix synthesis
4
Tyrosinase synthesis

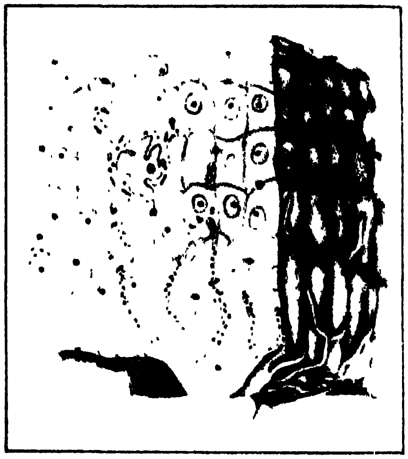
Formation of melanin in the skin

Some scientists believe that this disorder has a genetic basis and that it is transmitted to the offspring as an autosomal dominant (AD) characteristic with varying expressions of the inherited trait. An AD trait is one in which a single gene from either parent can affect the individual. There has been one record of identical twins having vitiligo which suggested a genetic basis. But, there was another case where only one of the identical twins acquired vitiligo. So, how far are genes responsible for the disease? Analyses of a number of individuals with vitiligo in various countries showed that only 35 to 38 per cent of them had a family history of it. For the rest, no genetic basis was possible.

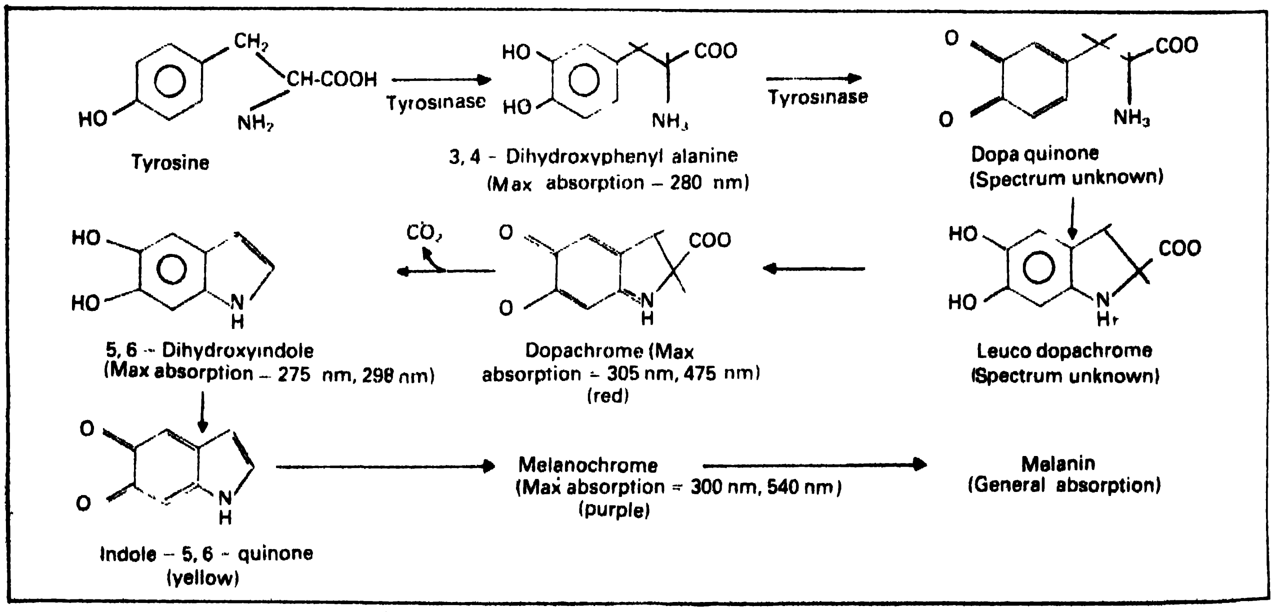
Another theory holds that trauma could lead to vitiligo, as in the case of Nicholas cited before. Trauma has long been accepted as a localising factor in vitiligo. For example, in my own case (A. Ramaiah), I remember that a depigmented patch of a size of pea appeared on the lower lip after an operation on the left hand at the age of 11, stayed stationary for about 22 years before it spread to other parts of the body.

By far the most attractive hypothesis is the neurological origin of vitiligo. Both pigment-forming cells, the melanocytes, and neuronal cells have a common origin in the embryo—the neural crest (see box on p. 57). When the inner neural crest is cultured in vitro, it differentiates into melanocytes, producing melanin. According to this theory which suggests a neurological origin to vitiligo, norepinephrine or some other catecholamine chemicals that transmit nerve messages are released in excessive amounts at the peripheral nerve endings in vitiligo patients. The excess is inactivated very slowly and these, during their prolonged presence, may prove toxic to melanocytes cells at that site. Most phenol or catechol derivatives, including certain melanin precursors like tyrosine dopa, dopachrome and 3-4 dihydroxyphenylalanine, in proper concentrations inhibit tyrosinase, the enzyme that converts tyrosine to melanin, and simultaneously destroy melanocytes.

Certain phenolic compounds and catechols used in industry, like p-tertiary butylphenol and p-tertiary amylphenols which are used as germicides and 4-tertiary butylcatechol



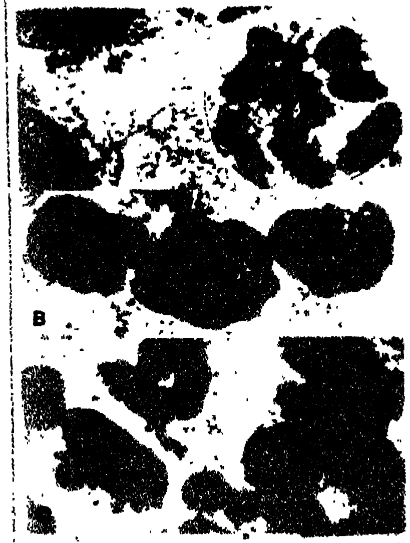
The epidermal melanin unit



Stages in the oxidation of tyrosine to melanin

How much colour does a man's skin need?

IT ALL depends on how the Sun shines on him. If his homeland is scorching hot, black would protect him best; its advantage is more than offset by the extra heat his skin will absorb. A white skin would get burnt. In fact there is usually a higher incidence of skin cancers in the white races and they are always warned to keep away from the Sun. For many animals, the colour of hair and fur is important for camouflage, for communication and radiation protection. In humans too it is mostly for protection against solar radiation. That it has acquired social and political significance is rather unfortunate.



A. Melanosome complexes from a malpighian cell of a Caucasoid. The complexes are surrounded by a membrane and contain small particles. B. Melanosome complexes from a malpighian cell of a Mongoloid. There is less ground substance between the melanosome than in A. C. Melanosomes in the malpighian cell of a Negroid. Almost all melanosomes are individually dispersed and are much larger than those in A and B (Magnified 50,000 times)

Mammals are unique in that they possess two separate but biogenetically interrelated classes of melanin pigments: the brown black enumelanins which are formed by the enzymatic oxidation of tyrosine and the pheomelanins ranging from yellow to reddish brown which arise from a deviation in the eumelanin pathway, through the interaction of cysteine with dopaquinone. Pheomelanins are often found in hair and feathers. The melanosomes containing pheomelanin are spherical while eumelanin-carrying melanosomes are ellipsoidal

Besides these pigments, there are two others in the human body, hemoglobin that gives blood its colour and carotenes which give body fats a yellow colour. All three pigments contribute to the normal colour of the skin but the racial differences are due to variations in the melanin content, size and shape of the melanosomes. The number of melanocytes, however, is the same in all races Exposure to sunlight induces the multiplication of melanocytes which also step up their melanin synthesis to protect from the over-exposure.

Melanin is a pigment produced by a network of specialised cells called melanocytes in the basal layer of the epidermis. The melanocytes are like nerve cells to which they are related; they have dendrite-like long slender projections. Both nerve cells and melanocytes are derived from the neural crest--a band of tissue on the neural tube in the developing embryo. In the melanocyte, tyrosine is enzymatically converted to melanin and stored in the intercellular structures called melanosomes. The melanin-laden melanosomes migrate towards the processes (projections) of the melanocytes, and are taken up by a layer of cells called keratinocytes. And the keratinocytes migrate towards the surface and give the skin its colour. In the dark skin, the melanosomes formed are large and well distributed. In the white and light skin, the melanosomes are small and clustered.

As regards hair, black, brown and blond colourations are due to melanin. The flaming red hair contains, in addition to melanin, an iron pigment.

In the vitiligo skin, the normal colouring process fails; sometimes the hair in the area also loses its colour. Premature greying occurs in 37 per cent of the cases, suggesting that they may be similar phenomena. However, hair greying is a result of changes occurring at the root.

Depigmentation can be controlled by certain tyrosinase-inhibiting chemicals. For example, by injecting hydroquinone, Negroes can be made as white as albinos permanently and by continuous treatment with psoralens, a Caucasian can be made to look coloured, although he would revert back to his natural colour by stoppage of this drug. Such treatments are not without their side-effects.

A. R.
I. H.

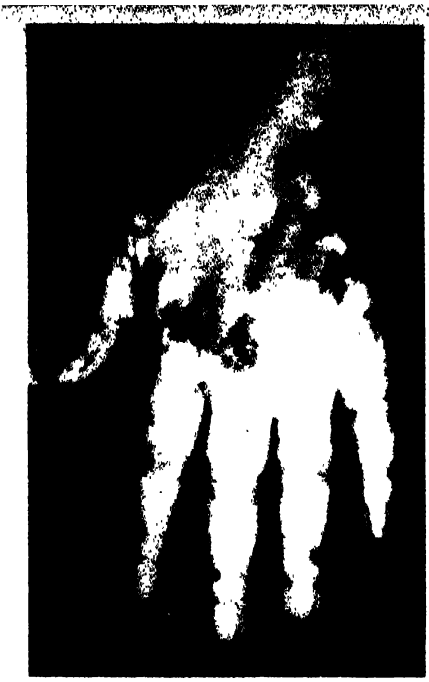
which is used in the manufacture of polyester resins, rubber, plastic and paint, could cause local depigmentation in individuals handling them for a long time. This process resembles vitiligo. The phenomenon of depigmentation of areas unexposed to these compounds, however, is not well understood. It may be an immunologic reaction resulting from sensitisation of lymphocytes after exposure to melanocytic antigens—antigens derived from dead melanocytes—which form on the death of the melanocytes in the exposed areas. These sensitised lymphocytes may then attack healthy melanocytes at distant locations.

Another theory deals with autoimmunity as a cause for vitiligo. Autoimmunity is a process where the defence mechanism of the body goes haywire; it fails to distinguish between self and non-self and thus produces antibodies against some of its own cells (SCIENCE TODAY, May 1980, p. 50). This self-destruction process, wherein a specific organ may be affected, leads to disease or malfunction. Ten per cent of the individuals who suffer from an autoimmune disease of one kind or another have vitiligo compared to one per cent in the general population. However, the proof for this theory is lacking in a majority of cases. So far only two individuals affected by vitiligo have shown melanocyte-destroying factors in their blood-complement-fixing factor that attaches itself to the melanocytes. Maybe, future tests with greater sensitivity will reveal the presence of specific antibodies to melanocytes in the sera of all vitiligo patients; till then, however, this hypothesis is only plausible.

Can it be cured?

In the normal skin, exposure to sunlight enhances the formation of pigments and it grows darker. This excess of pigmentation is meant to provide greater protection against the scorching effects of the solar radiation. In the case of vitiligo skin, the normal response is absent; instead, exposure results in sunburn.

To bring back colour into the white skin, Indians and Egyptians are known to have used extracts of the plant *bavachee (Psoralen corylifolia)*. The seed extracts were used both orally and topically, according to ancient Indian literature. The active principles of the seed extracts were identified as furocoumarins, that is, psoralens. When administered orally and followed by exposure to ultraviolet light (wavelengths 315 to 400 nm) of sunlight, pigmentation occurs in the affected skin in about 30 to 35 per cent of the cases. This treatment takes many months and these compounds are toxic to the liver. The toxicity to liver can be reduced by decreasing the level of these compounds in the blood. This is accomplished by allowing the patient to soak in a tub containing extremely dilute psoralen solution. By this, the concentration of the drug in the skin is kept high while that in the blood is kept low.



Depigmentation of the hand of a Negro laboratory worker who used an antiseptic containing 3 per cent p-tert-butylphenol. The spotty depigmentation rapidly developed over an 8-month period and resembles vitiligo. There is no depigmentation elsewhere on the skin

The mechanism by which psoralen acts is not clear: some experiments indicate that these compounds interact with DNA (deoxyribonucleic acid) resulting in the increased synthesis of tyrosinase which leads to an increased rate of pigment production. Additionally, these compounds result in the formation of larger melanosomes—pigment-bearing bodies—and help in their dispersion making the skin appear darker.

Corticosteroids have been used in partially successful treatment of vitiligo. However, their mechanism of action is not at all clear.

New findings

Knowing more about the disorder of course would help to design better preventive and curative methods. With financial help from the Department of Science and Technology, we have started working on the problem in our Institute. The questions we tackled are: (1) Does vitiligo skin contain melanocytes at all and, if so, can it synthesise melanin in vitro? (2) Are there any natural inhibitors of the enzyme tyrosinase in the melanosomes? These questions are important because if the melanocytes are not present in vitiligo skin, treatment should envisage the multiplication and migration of these cells from the borders of the vitiligo skin or from the hair roots of the vitiliginous area in case the hair in these areas is pigmented.

So far there were no conclusive answers to these questions. We tried biochemical methods to find the clue. Tyrosinase in the human epidermis is the marker enzyme for melanocytes. Therefore, the presence of this enzyme in the epidermis of the vitiligo skin should be proof of the existence of melanocytes, whether active or inactive. Homogenised vitiligo skin epidermis was tested for tyrosinase activity and its ability to incorporate uniformly labelled ^{14}C-*l*-tyrosine into melanin by following the rate of formation of its product dopa. The epidermal homogenates did exhibit tyrosinase activity and incorporated uniformly labelled ^{14}C-*l*-tyrosine into melanin. But their rates are only four to 37 per cent and 10 to 42 per cent respectively of the corresponding normal values. Since these results

Albinism

VITILIGO is often confused with albinism. Albinism is always hereditary and the depigmentation is complete, and is present at birth. Vitiligo occurs most often in patches. Rarely is the complete body involved, and it could start at any period of one's life. Vitiligo is shown to be hereditary only in about 30 per cent of the cases. Albinism is of two kinds, with the absence or presence of tyrosinase activity. The tyrosinase-negative albino can be distinguished from the tyrosinase-positive by a test called the hair bulb test. Bulbs of plucked hairs in growing phase will fail to darken and form melanin after prolonged incubation in vitro with tyrosine and dihydroxy phenylalanine (dopa). However, in the tyrosinase-positive albino, the hair bulbs darken rapidly. Ultrastructural studies of skin and hair show that in the tyrosinase-negative albino most of the melanosomes are without any melanisation. In contrast, the melanosomes of tyrosinase-positive albinism show some melanisation and, after incubation of the skin and hair in tyrosine dopa, most of them are fully melanised. However, most of the ultrastructural studies of vitiligo skin show the absence of melanosomes, though this is still controversial.

A. R.
I. H.

[illegible] and leucoderma

VAIDYA M. Y. Paranjape of Bombay suggests an ayurvedic treatment for leucoderma (*Journal of the Indian Medical Profession*, [illegible], 7084). He claims a considerable degree of success with patients of all age groups; however, he does not treat complete albinos and those with extensive depigmentation.

Mental worry, chronic or acute gastric disorders, impaired hepatic functions like in jaundice, worms are other parasites in the alimentary canal, typhoid and abnormal perspiration patterns are some of the factors, which according to Paranjape, trigger off leucoderma. He stresses that immediate attention should be paid to the first white spots which may appear anywhere on the body—either due to burns (by fire or acids), irritations like those from constant rubbing of leather footwear, surgical cuts, or septic wound or even an abrasion caused by vaccination.

Paranjape has developed a simple method combining surgery and herbal medication for the regeneration of skin pigments. Twice a day, the patient is orally given a dose of a special herbal mixture said to stimulate skin pigmentation, besides keeping the bowels clean and free of worms, etc. The mixture is made of *Physalis*, *Acacia*, *Cassia*, *Triphala*, *Rudrajuta* and *Warding*. Also, a tincture of *Rudrajuta* oil is applied externally on the affected area.

A superficial wound is made in the epidermal layer of the skin, after intradermally injecting a two per cent solution of procaine hydrochloride as a local anaesthetic. The 10 per cent *Rudrajuta* tincture which accelerates pigment formation is allowed to soak into the wound area for four to five minutes after which the wound is bandaged.

At regular intervals of three weeks, these simple cuts are then repeated at other white spots. After about three-to six weeks, new skin with healthy normal colouration appears and there are no scars, it is reported. Some patients have also been exposed to ultra-violet rays along with the herbal therapy.

There have been encouraging results for many patients, but others had to be punctured three times to evoke a response. And in some people, no improvement was observed. Avoiding oily and spicy food seems to enhance the chances of cure.

B. S. M.

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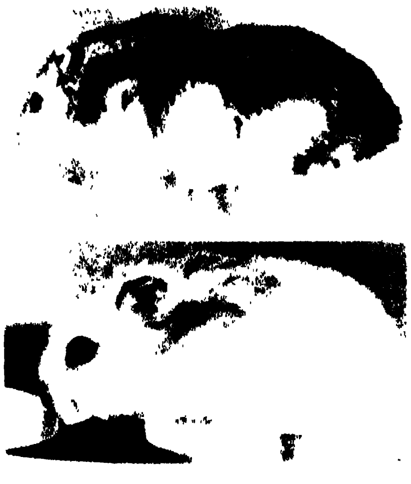
prove that vitiligo skin can synthesise melanin in vitro, the next question was what prevents the synthesis in vivo? During the investigations, we observed that the epidermis of normal skin contains in its melanosomes a protein which inhibits tyrosinase activity with its substrate tyrosine competitively. That is, both the protein and tyrosine react with the same site or overlapping sites on the enzyme. Whether there is an increase in the concentration of this protein in the melanosomes of epidermal melanocytes in vitiligo skin and whether this is in any way related to the lack of melanin are now under investigation. In addition, a natural de-inhibitor is actively being looked for in the normal and vitiligo skin.



The Siberian hamster in summer (top) and winter (above)

During these studies it was also observed that the tyrosinase activity is at least four to 10 times higher than the rate of melanin synthesis both in normal and vitiligo skin. This means that melanin synthesis is regulated at points also other than at the tyrosinase step. A similar conclusion was arrived at by other scientists using Siberian hamsters. Annual cycles of fur colour change occur in a variety of mammals and is particularly marked in species from sub-Arctic and north temperate zones. Siberian hamsters exhibit a striking colour change—the fur on the back being brownish grey in summer and almost snow white in winter. The changes from one condition to the other occur in the spring and in autumn months. These changes from the white coat to the dark summer coat can be prevented by injecting melatonin, and pinelectomy—removal of the pineal gland—keeps the coat colour dark independent of the season; this suggests that melatonin is one of the important compounds for the production of the unpigmented hair phase in the annual colour change cycle. Melatonin was shown to have no effect on tyrosinase or its increase in response to melanocyte-stimulating hormone (MSH) in vitro. This also suggests that the regulation of melanin synthesis is at points also other than at tyrosinase. However, no such role of melatonin on melanin synthesis has been found in humans.

Recently, three factors were found in melanoma cells—cancerous melanocytes—which may be involved in the regulation of melanin synthesis (p. 56): (1) a dopachrome conversion factor which accelerates the conversion of dopachrome to 5,6-dihydroxyindole; (2) a 5,6-dihydroxyindole conversion factor which accelerates the conversion of 5, 6- dihydroxyindole to melanin and is active only when cells are exposed to MSH, and (3) a 5,6-dihydroxyindole-blocking factor which restricts melanogenesis at the 5, 6-dihydroxyindole step. This factor also appears to protect cells from the cytotoxic effects of the melanin precursors.

It is likely that similar regulatory factors may be present in the melanocytes and may be involved in the regulation of melanin synthesis. Variations in any of these factors in vitiligo skin may explain the lack of melanin synthesis even in the presence of melanocytes. The next step in research would involve looking for these factors in normal and vitiligo skin.

Melanin synthesis and its control are complex than hiterto to believed, and the understanding of regulatory factors of melanin synthesis in normal melanocytes may help in delineating the defects in the vitiligo skin and hopefully to the correction of this defect.

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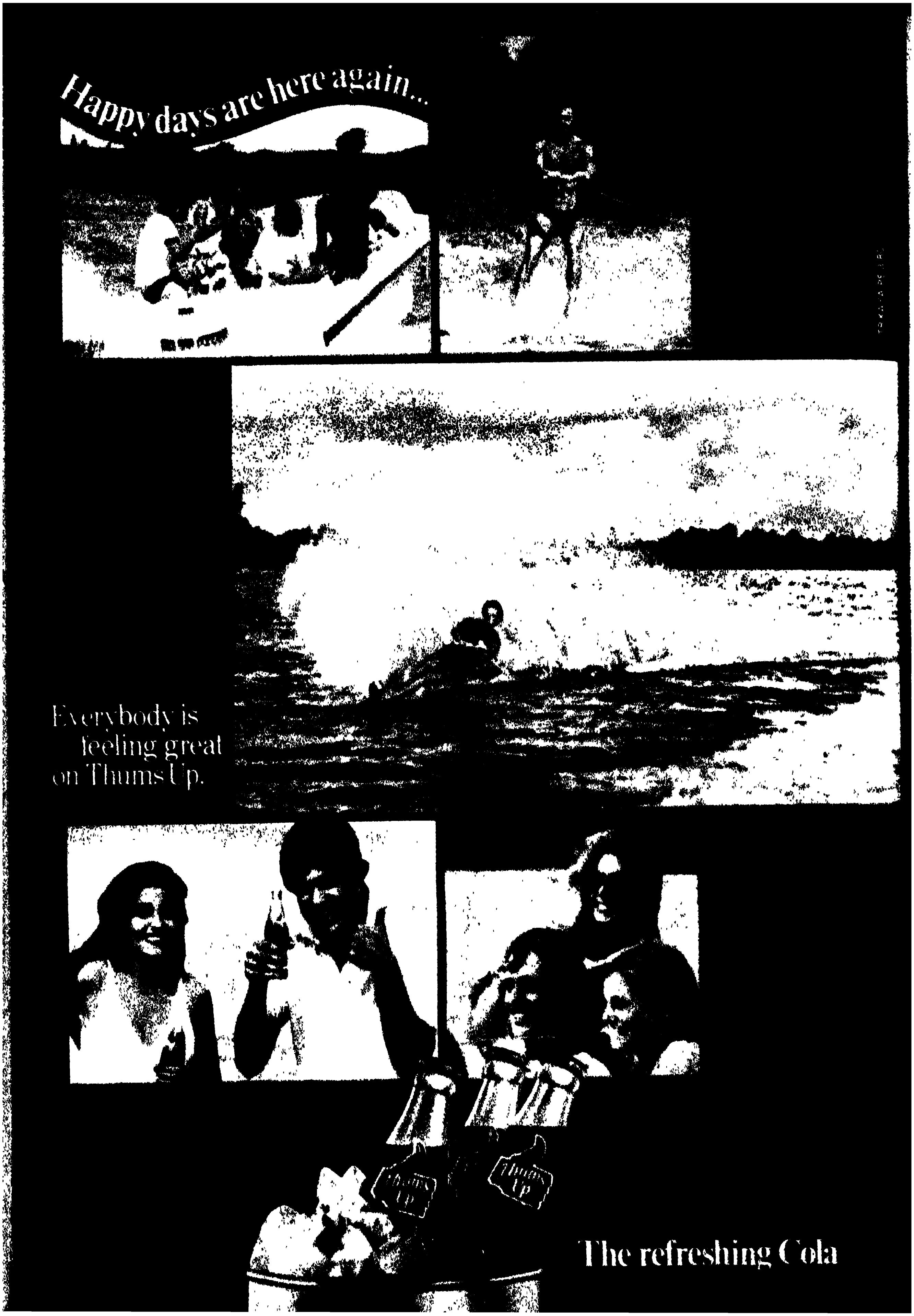
Mr. Husain did his MSc in biochemistry from Aligarh Muslim University. He has recently submitted his thesis for the Ph D degree on vitiligo at the All India Institute of Medical Sciences, New Delhi.

Recommend reading: **1.** Melanin pigmentation in mammals, Prota G. and Thomson R. H. *Endeavour*, **35**, 32, 1976; **2.** New regulators of melanin biosynthesis and the autodestruction of melanoma cells, Pawelek J., Korner A., Bregstrom A. and Bolagna J., *Nature* **286**, 617, 1980; **3.** Pelage color cycles and hair follicle tyrosinase activity in the Siberian hamster, Logan A. and Weatherhead B. *Journal of Investigative Dermatology* **71**, 295, 1978; and **4.** Vitiligo as a Kobner phenomenon, Sweet R. D. *British Journal of Dermatology* **99**, 223, 1978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micronutrients you can't do without

Walter Mertz

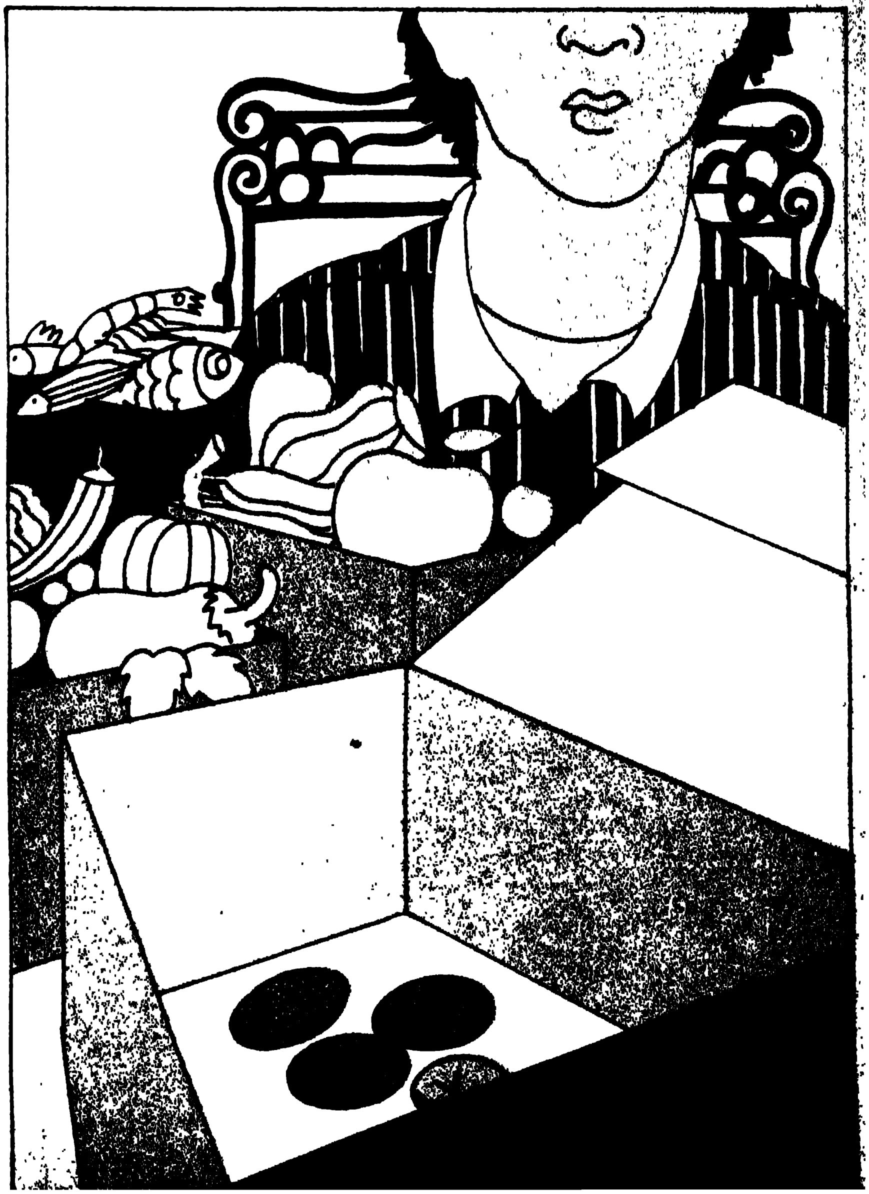
Many of our chronic diseases are of unknown or suspected multifactorial origin. Could they be due to trace element deficiencies?

THE bulk of living matter consists of hydrogen, carbon, nitrogen, oxygen and sulphur. The concentrations of these elements in biological matter can be expressed in grams per kilogram; they are required in gram amounts per day in humans. The macrominerals sodium, magnesium, phosphorus, chlorine, potassium and calcium serve as structural components of tissues, as constituents of the body fluids and are essential for the function of all cells. Their concentrations in living tissue and the adult human requirement are somewhat lower than those of the bulk elements, but still can be expressed as grams per kilogram and grams or fractions of a gram per day. The remaining elements of the periodic system occur in the organism in much lower concentrations and are expressed in terms of milligrams or micrograms per kilogram of tissue. Such concentrations were not easily quantified by the early analytical methods, hence the name "trace" elements.

Trace elements are best classified in two categories: those whose essentiality has been established by accepted scientific standards and those for which proof of essentiality does not exist. Research during the past three decades has added molybdenum, selenium, chromium, nickel, vanadium, silicon, and arsenic to the list of essential elements. This suggests that additional elements could be proved essential by future research.

By the simplest definition, an essential element is one required for maintenance of life. Severe deficiencies of an element that result in death are difficult to produce, particularly if the element is required in very low concentrations. A broader definition of essential elements has therefore been proposed and is widely accepted: an element is essential when a deficient intake consistently results in an impairment of a function from optimal to suboptimal and when supplementation with physiological levels of this element, but not of others, prevents or cures this impairment. Essentiality is generally acknowledged when it has been demonstrated by more than one independent investigator and in more than one animal species. By these criteria, the following trace elements are now considered essential in animals: silicon, vanadium, chromium, manganese, iron, cobalt, nickel, copper, zinc, arsenic, selenium, molybdenum and iodine. Growth depression resulting from deficiency of fluorine and tin and growth stimulation following supplementation with these elements have been reported but not yet confirmed. Nevertheless, fluorine can be considered essential on the basis of its demonstrated effect on dental health

The degree to which a function is impaired in an animal with a defi-



ciency is not related to the criterion of essentiality but depends on the degree to which exposure of the test animal to the trace element—by way of diet, water and air—can be controlled. Such control is easy for elements that are required in relatively high concentrations, such as iron and zinc, but is difficult and requires special precautions for those that are required in much smaller concentrations, such as selenium, chromium, vanadium, nickel and arsenic.

The dependence of the severity of signs and of the effects of resupplementation on the degree of deficiency was formulated mathematically by G. Bertrand at the beginning of this century. The rule states that a function for which a nutrient is essential is very low or absent in a theoretical, absolute deficiency, and increases with increasing exposure to the essential nutrient. This increase is followed by a plateau representing the maintenance of optimal function through homeostatic regulation, and a decline of the function toward zero as the regulatory mechanisms are overcome by increasing concentrations that become toxic. Although each essential nutrient has its own specific curve, the principle of Bertrand's model is probably applicable to all essential nutrients, including the bulk elements, water and oxygen, as well as the individual trace elements. Two conclusions from this model are relevant to the understanding of trace element research: (i) for each element there is a range of safe and adequate exposures, within which homeostasis is able to maintain optimal tissue concentrations and functions; and (ii) every trace element is potentially toxic when the range of safe and adequate exposure is exceeded.

Past trace element research has demonstrated essential functions for at least three trace elements, selenium, chromium and arsenic, which previously had been known only as toxic. These examples have important implications for the quality of the environment and for present efforts to reduce exposure to "toxic" elements to a minimum. Although adequacy of trace element metabolism is strongly influenced by a multitude of dietary interactions, safe and adequate intakes are reasonably well defined for iron, zinc and iodine. Ranges have been estimated for fluorine, chromium, manganese, copper, selenium and molybdenum, but are unknown for the "new" trace elements, vanadium, nickel, silicon and arsenic.

Table 1. [illegible] *dietary intakes for adults.*

Element	Intake (mg/day)
Iron (males)	10
Iron (females)	18
Zinc	15
Manganese	2.5 to 5.0
Fluorine	1.5 to 4.0
Copper	2.0 to 3.0
Molybdenum	0.15 to 0.5
Chromium	0.05 to 0.2
Selenium	0.05 to 0.2
Iodine	0.15

In an adult human, the daily turnover of cobalt as a constituent of vitamin B_{12} is between 100 and 150 nanograms per day, corresponding to approximately 2 parts per trillion of the adult body weight; the average vitamin B_{12}-cobalt concentration in blood approximates 5 ng/litre. Deficiency of vitamin B_{12} results in a serious disease, pernicious anemia. Although other trace elements, such as iron, copper and zinc are present in the organism in much higher concentrations, the example of cobalt challenges the scientist to explain how small traces of an element profoundly influence functions that are essential for health, and how they are recognised by the organism and transported to their ultimate site of action. Our knowledge of the chain of events linking the ionic property of a trace element to the expression of a health-related function in the whole organism is incomplete, but some parts of this sequence can be discussed.

Amplification. All known essential trace elements are constituents of or interact with larger molecules, such as enzymes or hormones, that, in turn, regulate much larger masses of substrate. If this substrate itself has some regulatory function, the effects are further amplified to a degree that could relate to the overall effect of the trace element in the intact organism.

Specificity. The effects of trace elements in vivo are absolutely specific: a deficiency of one element can be prevented and remedied only by that, but not by another, element, even if the latter is chemically related to the first. If anything, the severity

Table 2. Classification of the essential trace elements.

Element	Function	DEFICIENCY
		Humans
Fluorine	Structure of teeth, possibly of bones; possibly growth effect	Increased incidence of caries; possibly risk factor for osteoporosis
Silicon	Calcification; possibly function in connective tissue	Not known
Vanadium	Not known	Not known
Chromium	Potentiation of insulin	Relative insulin resistance, impaired glucose tolerance, elevated serum lipids
Manganese	Mucopolysaccharides metabolism, superoxide dismutase	Not known
Iron	Oxygen, electron transport	Anemia
Cobalt	As part of vitamin B_{12}	Only as vitamin B_{12}; deficiency
Nickel	Interaction with iron absorption	Not known
Copper	Oxidative enzymes; interaction with iron; cross-linking of elastin	Anemia, changes of ossification; possibly elevated serum cholesterol
Zinc	Numerous enzymes involved in energy metabolism and in transcription and translation	Growth depression, sexual immaturity, skin lesions, depression of immunocompetence, change of taste acuity
Arsenic	Not known	Not known
Selenium	Glutathione peroxidase; interaction with heavy metals	Endemic cardiomyopathy (Keshan disease) conditioned by selenium deficiency
Molybdenum	Xanthine, aldehyde, sulphide oxidases	Not known
Iodine	Constituent of thyroid hormones	Goitre, depression of thyroid function, cretinism

of the deficiency is aggravated by excesses of chemically similar elements. This specificity of trace element action in vivo contrasts with the much less specific behaviour of trace elements in vitro. It is known that in at least two metalloenzymes the specific element zinc can be replaced in vitro by other transition metals, such as cadmium and cobalt, with little loss of overall enzyme activity but with a change of the enzyme's affinity for substrates. Enzymes that do not contain a trace element as an integral part but are activated by metals, respond to in vitro addition of several transition elements with a dose-dependent activation. This suggests that the high degree of specificity in vivo is brought about by carriers with specific sites that recognise a certain element when it enters the organism and delivers it to its own sites of action, but not to others. The mechanisms that govern the association of an element to its carrier and its subsequent dissociation to its site of action are not known. Among the large carrier molecules are plasma proteins, such as transferrin, ceruloplasmin, albumin, macroglobulin, transmanganin and nickeloplasmin. In addition, a fraction of the trace elements in serum is carried in the form of amino acid or small peptide complexes. The binding capacity of specific protein carriers is usually undersaturated. Under normal conditions, for example, transferrin carries only one-third of its maximum iron load. The reserve binding capacity can be considered an effective buffer against excessive exposures; toxicity from nonspecific organ distribution of trace elements usually results only after this buffering capacity is exceeded.

The carrier substances assure the delivery of trace elements to their specific sites of action. At these sites, the action of a trace element is specific and is dependent on properties such as valency state, redox potential, ionic radius, coordination number, coordination geometry, spin state (high versus low spin transition), and rate of ligand exchange. These properties, in their entirety, clearly distinguish one element from another. And the property of trace elements, particularly those that are transition elements, to form coordinate compounds is the chemical basis of their biological action.

Homeostatic regulation. The organism has powerful mechanisms that maintain the plateau of optimal function in the biological dose-response curve throughout a wide range of dietary and environmental exposure. Comparable extremes of some macronutrients, such as water, salt, or protein over extended periods of time would be incompatible with health. The buffering aspect of homeostasis already has been discussed: the specific carrier substances of trace elements are normally less than fully saturated and thus present a certain buffering capacity against excesses, but control of absorption or excretion mechanisms, or both, is quantitatively more important.

Gastrointestinal absorption of trace elements occurs in three different phases: (i) the intraluminal phase with its chemical reactions and interactions of elements in the stomach and intestines; (ii) the translocation phase, that is, diffusion or transport of the element across the cell membrane of the epithelial lining; and (iii) the mobilisation phase, including mobilisation and transport of the intracellular elements into the blood stream or their sequestration back into the intestinal lumen.

The chemical reactions during the intraluminar phase are dominated by the pH of the luminal contents and by the composition of the food entering the stomach. Small anionic elements such as fluorides, selenites, and iodides are not much influenced by either *p*H or dietary composition and are absorbed quite freely, whereas the cationic forms of the transition elements are highly dependent on both influences. These cations, while freely soluble in the acidic *p*H of the stomach contents, would form insoluble hydroxides in the alkaline *p*H of the intestines and become unavailable for absorption unless protected by ligands that successfully compete with hydroxyl ions. Thus, the nature of the ligands that form coordination or chelate compounds with the elements is an important determinant of bioavailability. Such coordinate compounds or chelates may be present in the diet and absorbed into the epithelial cell unchanged, as is the case for the heme iron complex. Alternatively, they may be hydrolysed in the acidic milieu of the stomach and give way to new associations with dietary or secreted substances having greater affinity to the metal involved. Amino acids and other organic acids and

SIGNS Animals	Occurrence of imbalances in humans
Caries; possibly growth depression	Deficiency and excess known
Growth depression; bone deformities	Not known
Growth depression, change of metabolism	Not known
Relative insulin resistance	Deficiency known in malnutrition, aging, total parenteral alimentation
Growth depression, bone deformities, β-cell degeneration	Deficiency not known; toxicity by inhalation
Anemia, growth retardation	Deficiencies widespread
Anemia; growth retardation in ruminant species	Inability to absorb vitamin B_{12} intake from vegetarian diets
Growth depression, anemia.	Not known
Anemia, rupture of large vessels, disturbances of ossification	Deficiencies in malnutrition, total parenteral alimentation
Failure to eat, severe growth depression, skin lesions, sexual immaturity	Deficiencies in Iran, Egypt, in total parenteral nutrition, genetic diseases, traumatic stress
Impairment of growth, reproduction	Not known
Different, depending on species: muscle degeneration (ruminants), pancreas atrophy (chicken)	Deficiency and excess in areas of China; one case resulting from total parenteral alimentation
Difficult to produce; growth depression	Associated with goutlike syndrome
Goitre, depression of thyroid function	Deficiencies widespread; excessive intakes may lead to thyrotoxicosis

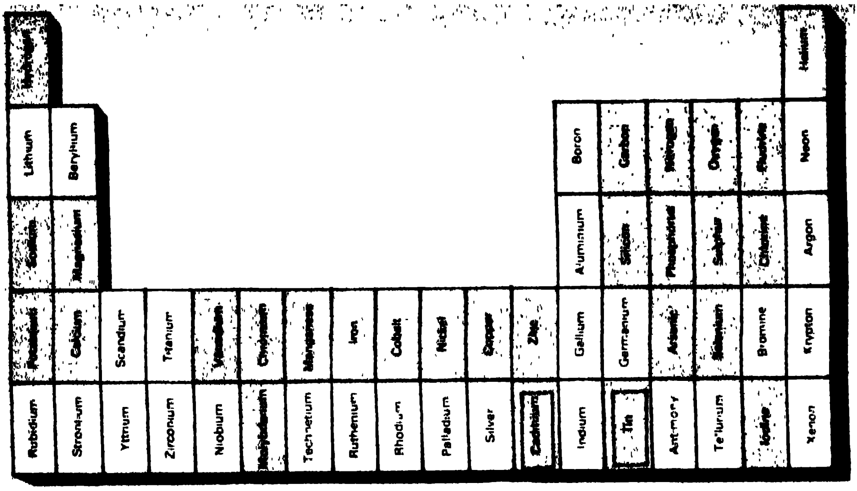


Fig. 1 Part of the Periodic Table showing all elements accepted as essential(green). Red borders indicate unconfirmed reports of growth stimulation

sugars and their derivatives are examples of important ligands. It is not known whether the metal complexes or chelates are absorbed intact or whether they are dissociated at the cell surface prior to the absorption of the metal.

The second phase, translocation across the cell membrane, may be a simple diffusion for small anions but is the facilitated diffusion or active transport for most of the cationic elements. Both of these two last mechanisms are saturable: the relative rate of transport decreases with increasing concentration, and this is one important aspect of regulating absorption. For at least one macroelement, calcium, a direct hormonal regulation of the active transport phase of intestinal absorption has been demonstrated; it is not known whether such regulation also determines the active transport of the trace elements.

The events within the intestinal epithelial cells are not well known in general, but specific mechanisms have been postulated for two trace elements, iron and zinc. These elements, once absorbed into the cell, are bound to specific storage proteins, ferritin and metallothionein, respectively. Thus, depending on the relative concentration of these proteins and of the entering ions and on the equilibrium constants, a variable proportion of the absorbed elements remains free for further reactions that initiate mobilisation into the general circulation. If the concentration of the binding proteins is relatively high, a greater proportion of the entering ions is bound, and a proportionally smaller part of the absorbed elements is available for transport into the circulation. As the epithelial cells are replaced by younger cells and sequestered into the intestinal lumen, the storage proteins and the elements bound to them are lost to the organism and become part of the intestinal content. It is known that the concentration of metallothionein in organs can be increased by administration of the trace elements that they specifically bind. On this basis, a feedback mechanism regulating zinc absorption has been postulated: increasing concentrations of zinc in the plasma stimulate increased metallothionein synthesis in the intestinal cells, which leads to a greater trapping of absorbed zinc and eventual loss by desquamation and a relative decrease of the functional supply to the organism. As the plasma zinc concentration declines, the stimulus for metallothionein synthesis diminishes, and the portion of absorbed zinc available for transport into the circulation is correspondingly increased. Mechanisms of this nature may be the predominant regulators of homeostasis for iron, zinc, copper, and possibly other elements, for which regulation by urinary excretion is relatively insignificant.

The major routes of excretion of trace elements are intestines and kidneys; losses of trace elements via skin and its appendices, and sweat and breath also can become important in hot climates and, for selenium, during overexposure. These excretory routes, however, are slightly or not at all subject to homeostatic regulation. Excessive intakes of these elements are effectively excreted by the kidney, whereas the homeostasis of manganese is predominantly regulated by control of excretion into the intestines. The physiological and biochemical mechanisms that govern homeostasis by regulation of excretion are not known but, with normal kidney function, protein-bound trace elements are not removed and excretion is limited to small molecular species.

Trace element deficiencies in man and animals

Much information about deficiency signs and their consequences has been amassed for animal species and man (Table 2). Here I describe only the present state of nutritional trace element research by discussing three elements that can serve as examples of three stages of progress: the first stage is based on iodine, the second on chromium and the third on silicon.

Iodine. Although the first convincing association between iodine and thyroid function was established 130 years ago, sources of iodine, such as burnt sponges, were used for many centuries as an effective treatment for goitre. The only known function of iodine is as the active component of the thyroid hormones triiodothyronine and thyroxine. The mechanism of synthesis of these hormones is known. There is no understanding yet, however, of why the addition of three or four iodine molecules transforms a biologically inert compound, thyronine, into a powerful hormone that controls energy metabolism in

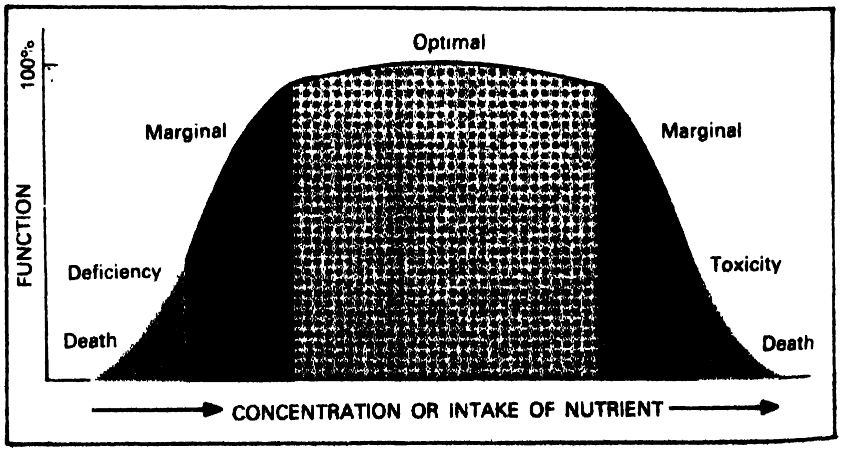


Fig. 2 Dependence of biological function on tissue concentration on intake of nutrient

all species, biological transformation in Amphibia, and even mental attitudes and intellectual performance in man. In spite of the wide distribution of iodine throughout the organism, especially in the ovaries, no extrathyroidal functions for this element have been established. However, iodine deficiency per se, regardless of thyroid function, is associated in experimental animals with dysplasia of the mammary gland that responds to supplementation with inorganic iodine, but not with thyroid hormones.

The iodine status of animals and man is strongly dependent on iodine concentrations in soil, water, and air. Although this environmental influence is modified by interactions with goitrogens that interfere with the utilisation of iodine and by interactions with several trace elements, the worldwide maps of goitre incidence in populations are generally superimposable on those delineating low iodine concentrations in soils. Public health measures of increasing the iodine intake in deficient areas through fortification of table salt or bread have been effective, when properly designed and executed, as shown by the substantial reduction in goitre incidence in the "goitre belt" of the United States. Yet, iodine deficiency remains a problem, affecting hundreds of millions of people worldwide. This may be due to insufficient levels of iodisation of carrier substances that fail to furnish the estimated requirement of 75 to 150 µg/day, or it may be due to logistical difficulties in developing countries or to food laws prohibiting the addition of iodine.

The nutritional importance of iron also has been studied for decades. Although iron and iodine differ in many aspects of nutrition, metabolism and deficiency, the following conclusions apply to both elements:

1) Deficiency results in serious disease in man and animals; toxicity is known for both but is not as great a health problem as deficiency.

2) Deficiencies affect hundreds of millions of people, and geographical problem areas are known. Individual supplementation is effective in preventing deficiencies. Public health measures of iodisation have been proved effective. Substantial reduction of the goitre incidence is scientifically feasible; it depends on political decisions and economic considerations.

Chromium. The essential function of chromium for maintenance of normal glucose tolerance in rats was established in 1959. This discovery was based on observations of impaired glucose tolerance in rats raised on purified diets that were complete with regard to all essential nutrients known at that time. The impairment of glucose tolerance was prevented by certain feed ingredients, such as brewer's yeast, and was cured by one dose of concentrates from brewer's yeast or kidney powder. After five years of purification and fractionation, the active ingredient was identified as trivalent chromium, which, in microgram quantities and in the form of certain inorganic complexes, prevented and cured the impairment of glucose tolerance in the experimental animals. Inorganic chromium compounds, added in vitro to epididymal fat tissue of chromium-deficient rats and Krebs-Ringer phosphate medium containing glucose, stimulated glucose uptake from the medium, but only in the presence of insulin. Utilisation of glucose for oxidation and fat synthesis was equally affected by chromium, as was the transport across the cell membranes of D-galactose, a sugar that is not further metabolised within the fat cell

These experiments suggested that chromium acted at the first step of sugar metabolism, cell transport, where insulin also exerts its primary action. Further studies in vitro and in vivo demonstrated that general insulin resistance was a consequence of chromium deficiency that could be prevented and cured by chromium administration. The fact that chromium is ineffective in the absence of insulin, and its demonstrated effect in vitro to increase the slope of the insulin dose response of chromium-deficient tissue, indicated that chromium is not an insulin-like agent but a true potentiator of the hormone.

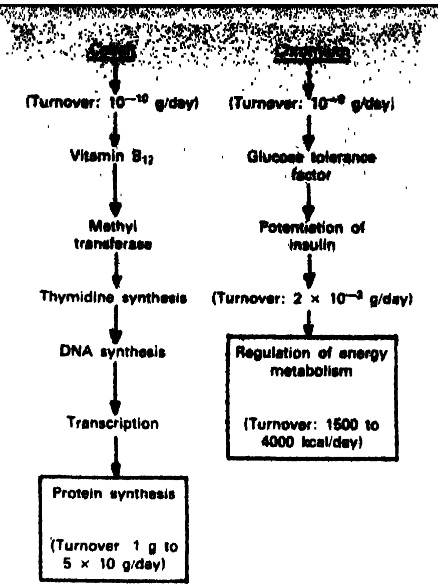


Fig. 3 Amplification of trace element action.

Pronounced chromium deficiency produced in an environment that allows exclusion of trace element contamination resulted in a diabetes-like syndrome in rats, with fasting hyperglycemia, glycosuria, elevated serum cholesterol, and a high incidence of fat deposits in the aorta.

Chromium deficiency in human subjects cannot yet be reliably diagnosed by chromium analysis of body fluids or tissues. Its recognition depends on retrospective diagnosis: insulin resistance, manifested by impaired glucose tolerance in the presence of normal or even elevated concentrations of insulin, that is normalised by supplementation with physiological amounts of chromium. Two carefully controlled clinical cases of total parenteral nutrition have been reported independently (the patients had been sustained exclusively by administration of intravenous fluids). Both patients developed glucose intolerance, insulin resistance, and disorders of the central or peripheral nervous system, all of which were normalised after chromium, but not after insulin, administration. Chromium-responsive impairment of glucose tolerance has also been reported in a large proportion of malnourished children studied in Jordan, Nigeria, and Turkey, but not in Egypt. Studies in the United States on middle aged and elderly subjects with impaired glucose tolerance generally detected an improvement in one-third to one-half of the subjects, after chromium supplementation. A series of more recent studies demonstrated a significant reduction of total serum cholesterol in human subjects who were supplemented either with inorganic chromium or high-chromium brewer's yeast preparations. There was a strong lowering of the low-density lipoprotein cholesterol, with a simultaneous increase of the high-density lipoprotein cholesterol.

The daily human requirement for chromium has been estimated at 50 to 200 µg. Without a reliable diagnostic test for chromium status, the incidence and severity of chromium deficiency cannot be evaluated. Yet, chromium deficiency can be implicated as a significant risk factor for cardiovascular disease on the basis of animal studies and epidemiological as well as clinical correlations in human subjects.

Chromium was discussed in some detail as representative of the second stage of progress of trace element research, that is also representative for copper, zinc, and selenium. Although modes of action and signs of deficiency differ among these elements, several nutritional aspects are common to all and can be discussed together.

1) Serious deficiencies in human subjects have been described; those of zinc in Iran and of selenium in China are of considerable public health importance. The signs of deficiency are compatible with the known mechanisms of action.

2) The daily requirement of humans can be estimated, and recommended allowances or "estimated ranges of safe and adequate intakes" have been established.

3) Although pronounced deficiencies in the free-living population of the US are very rare, dietary surveys have shown that average intakes far below the recommendations for copper and zinc are quite common in the US population. Intakes of chromium and selenium range from adequate to marginal, depending on country and region.

4) The important question remains whether marginal deficiencies, difficult to diagnose for any of the four elements, occur to any substantial degree and present a risk to the health of people. Valid experimental data show that zinc is required not only for growth and development but also for tissue repair and immuno reactions and that selenium protects animals against chemically or virally induced malignant tumours. Both chromium and copper influence recognised risk factors for cardiovascular disease in experimental animals. The question can be answered only by long-term, prospective studies of population groups that are at risk.

5) The adequacy of the dietary intake is difficult to assess for all four elements because the biological availability of each differs among foods and because the numerous interactions among the elements and with other dietary components are difficult to quantify. For example, foods of animal origin are better sources of chromium and zinc than food of vegetable origin; the opposite is true for selenium. Vitamin C enhances the biological availability of iron, depresses that of copper and, in vitro, renders selenium nearly totally unavailable. These and many additional interactions complicate the task of assessing, even superficially, the adequacy of trace element intakes of individuals or population groups. They also point out the danger of creating new imbalances by self-supplementation with vitamin or trace element preparations.

6) No sensitive diagnostic assays are available to assess marginal nutritional status for these four trace elements, in contrast to the sensitive and reliable methodology for iron and iodine.

The nutritional and public health problems of the trace elements at the second stage of research can be summarised as follows: severe deficiencies can be recognised from clinical signs and remedied. The main nutritional problem in developed countries is the recognition of marginal deficiencies, definition of their consequences, and, if necessary, their prevention.

Silicon. Although silicon had been known as a regular constituent of biological materials since the beginning of the century, 90 years passed between the prophecy of Louis Pasteur "effects of silicic acid are destined to play a great and major role in therapy" and the first demonstration that strongly suggested that silicon may have an essential biological function. E. M. Carlisle demonstrated by electron microprobe analysis that silicon accumulates to concentrations of 0.5 per cent in a narrow zone of ossification of bone, exceeding the concentration of calcium by tenfold. In the more mature zones of bones with the beginning of calcium deposition, the silicon concentration sharply decreases again. Subsequently, proof of essentiality for silicon was independently established by two investigators in chicks and rats using similar methods. Their findings were also similar: both species responded to supplementation with sodium metasilicate (500ug/g in the diet) with a 30 to 50 per cent growth stimulation and both developed severe bone deformities, particularly of the skull, when raised on the silicon-deficient diet. Silicon supplementation, in addition to stimulating growth, maintained normal bone structure. Thus, silicon can be considered an essential trace element.

The mechanism of action of silicon is not yet known, but three potential sites of action have been suggested Silicon is present in high concentrations in mucopolysaccharide-rich tissues, and a proportion of the total amount of the element is bound so tightly that it can be hydrolysed only by strong acid or alkali treatment. As the most pronounced effect of experimental deficiency is a reduction of the glycosaminoglycans in cartilage, a possible role of silicon in these structures has been suggested. Silicon also occurs in high concentrations and in part firmly bound in collagen, and collagen concentrations in bone are depressed in silicon deficiency. An early hypothesis of a general cross-linking function of silicon in collagen on the basis of one atom of silicon per alpha chain was later revised when it had become obvious that the analytical data on silicon were erroneous, but a cross-linking function at a few, specific sites would still be compatible with more recent analytical data. Finally, silicon is specifically concentrated in the mitochondria of the bone-forming cells, the osteoblasts. While in the whole cells calcium to silicon ratios are approximately 5 to 1, the silicon concentration within the mitochondria exceeds that of calcium.

The silicon requirement of man is unknown and nutrient composition data for silicon are few and unreliable. Furthermore, it can be predicted that silicon will present many problems of biological availability, depending on dietary source. Despite this lack of reliable nutritional information a protective role of silicon against cardiovascular diseases has been postulated, in part on the basis of negative correlations between the silicon content of water in Finland and the incidence of cardiovascular diseases, the substantial decline of silicon concentrations in atheromatous aorta tissue, and the results of animal experiments suggesting that silicon, administered to animals on an atherogenic diet, helps preserve the structural integrity of the aorta.

Silicon was discussed as an example of trace elements in the third stage of research that also include vanadium, nickel, and arsenic. All these elements were postulated to be essential during the past decade, their basic mechanisms of action have yet to be defined, their deficiencies are difficult to induce, and their roles in human nutrition are unknown. A practical role in humans of any of these can neither be predicted nor excluded. In the developed, industrialised societies the exposure of humans to trace elements from diet and environment has changed during this century, and the change can be expected to continue. Furthermore, many of our chronic diseases of major public health importance are of unknown or of suspected multifactorial origin, and theories on their etiology are open to new ideas that might involve any of the new trace elements. Such ideas, however, must be based on knowledge of their basic mechanisms and sites of action, of human requirements for these elements, and on the definition of nutritional status in man.

Dr. Mertz is director of the Beltsville Human Nutrition Research Center, Science and Education Administration, US Department of Agriculture, Beltsville, Maryland. This somewhat abridged article first appeared in *Science* Copyright © 1981 AAAS

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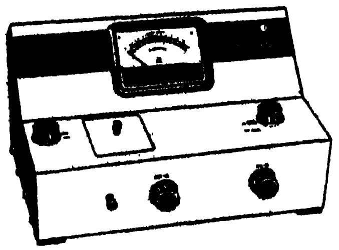

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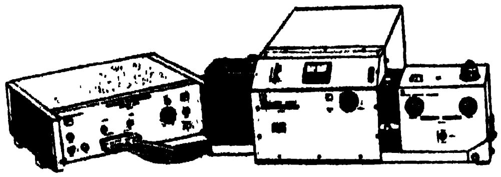

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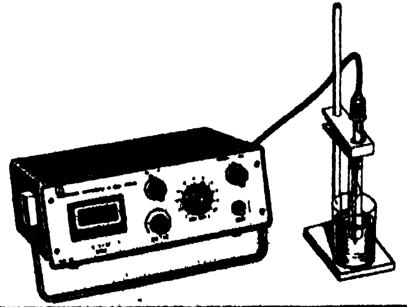

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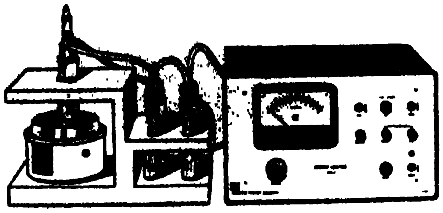

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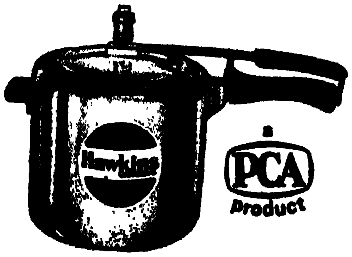

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TELL US...

... how do people walk on fire?

WALKING barefoot on burning fire never fails to evoke cries of awe and astonishment from the onlookers. And while the spectators gape at this marvel, the fire-walker triumphantly walks across the embers, completely unaffected. Naturally, amongst the majority of masses, this 'safe sojourn' is attributed to the religious faith of the fire-walker. Many view it as a miracle or a supernatural phenomenon.

Practised widely in many parts of India, Sri Lanka and other South-east Asian countries, one of the earliest reports in scientific literature on burn-free fire-walking is of 1935, when a Kashmiri magician, Khuda Bux visited England and gave demonstrations in the presence of university teachers, investigators and physicians. A professor took the temperature of his sole and an Oxford physician examined his feet just before a demonstration. The soles were observed to be very cold (93.2 degrees centigrade) and thick. Khuda Bux washed his feet and soon after took four strides through the fire-bed. His feet were found to be uninjured and free of blisters after the demonstration.

However, a real breakthrough in explaining the principle underlying the practice of walking on fire was made by Dr Carlo Fonseka of the Department of Physiology of Colombo Medical College, Sri Lanka. The reason why people, during a traditional fire-walking ritual,do not burn their feet is because the duration of contact of their feet with fire is short and the feet are wet, cold and dirty, opines Dr Fonseka. Experiments were conducted in his laboratory. He reconstructed a bed of red hot cinders of the size used in various places of religious worship for the walking-on-fire ceremony. He invited religious heads, scientists and leaders of public opinion and in their presence asked five healthy adult men to walk boldly across the fire. Men from the audience were also invited to come forward and verify for themselves the truth of his statement.

Dr Fonseka, after observing many fire-walking displays in Sri Lanka, measured the dimensions and the surface temperatures of the fire-beds, the time taken by each fire-walker to traverse the fire, the number of times the feet of the fire walker came in contact with fire and the number of steps taken to traverse the fire bed.

Hence, Dr. Fonseka worked out the actual duration of contact of the feet of the fire-walker with the red hot embers while crossing the fire-bed. It ranged from 0.2 second for the fastest to 0.6 second for the slowest person. The average was 0.3 second. The physical stimulus in fire-walking was 300°C to 450°C of heat and the responding tissue involved was the thick sole of the fire-walker's foot.

Normally, the skin surface temperature is lower than that of the deeper tissues. When a very hot object is applied to the skin and the duration of application is long, its temperature rises. Heat now flows inwards from the skin surface to the deeper tissues, raising the temperature of the latter. A burn results when the temperature reaches a critical level of about 50°C. A blister or a scald is formed when liquid plasma oozes out from the deeper tissues and collects under the burnt dead superficial layer of the skin. It is formed even when the burn is caused by hot gaseous steam, contact of boiling liquid or a solid red hot piece of metal.

A basic rule in physiology is that to be effective, a stimulus must act for a certain minimum duration of time, below which no response is produced no matter how strong the stimulus may be. In the case of traditional fire-walking,the stipulated response—rise in the temperature of the deeper tissues and consequent production of a burn—does not occur because the application of the stimulus is shorter than the required critical duration.

A practical application of this principle is seen among villagers when they lift a red hot burning charcoal with bare hands and put it on their smoking pipe. It is noticed that the villager does not hold the hot cinder continuously but plays it all the time in his palm, so that the contact with the skin of the hand at no time exceeds more than 0.3 second and thus no pain or burn is caused. For the same reason a bit of heated metal can also be picked up with the same ease. But, one will not be able to dip his finger in a liquid, heated to the same temperature, without harm. Because, besides making a contact over a wider area, the liquid tends to cling on to the finger surface and heat it for a longer period.

Test by fire

Most of the devotees who practise fire-walking are habitually barefooted, and therefore have thick rough soles. Moreover, just before the ceremonial act commences, the fire-walkers take a bath in a river or a pond and come to the site of fire-walking in wet clothes and with bare feet which get smeared with mud. These factors also play a part in protecting the body from injury while walking on fire. The mud acts as an insulator between the sole and the fire just as a cloth, used to pick up a hot utensil from a stove, provides insulation between the fingers and the hot metal. Water dripping from the loin cloth also helps to cool down the rising temperature of the soles.

Most of the fire-walkers are adults and young children are rarely seen. Children's skin is tender and more vulnerable to burns than that of adults. But, the young ones make up their weakness by walking fast, giving thereby less time for their soles to come in contact with fire.

One other related performance, practised commonly at places of entertainment, is the act of fire-swallowing. Here, a lighted ball of fire at the end of a wire, is held in the cavity of the mouth for a short period of time, without injury to the lining of the inner wall. How is this achieved? Fire-swallowing has not been scientifically investigated, but it is obvious that three factors play a part in protecting the tissue from injury. Firstly, the moisture of saliva, that is always present, helps to guard the oral mucous membrane. Also,the inert carbon dioxide in the expired air tries to extinguish or at least keep down the burning flame. Thirdly, the inner lining of the mouths of these men is comparatively rough due to repeated performances and heat exposures.

Here, one recalls the Biblical practice of testing a person's honesty by asking him to swear by touching the tip of his tongue to a red hot sword. The rationale behind this ordeal was that fear would make a liar's mouth parched dry and his tongue would burn on touching the heated metal directly. But in a honest person, the thin moist layer of saliva would protect him.

Now, it is hoped that the readers will have no hesitation in partaking in a ceremony when they witness one next. They will also, to be doubly safe, follow faithfully all the traditional customs of coming to the site of fire-walking in a wet dripping loin cloth and with as much mud on their feet as possible!

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Dr. Rao was formerly Professor of Physiology, Gandhi Medical College, Hyderabad

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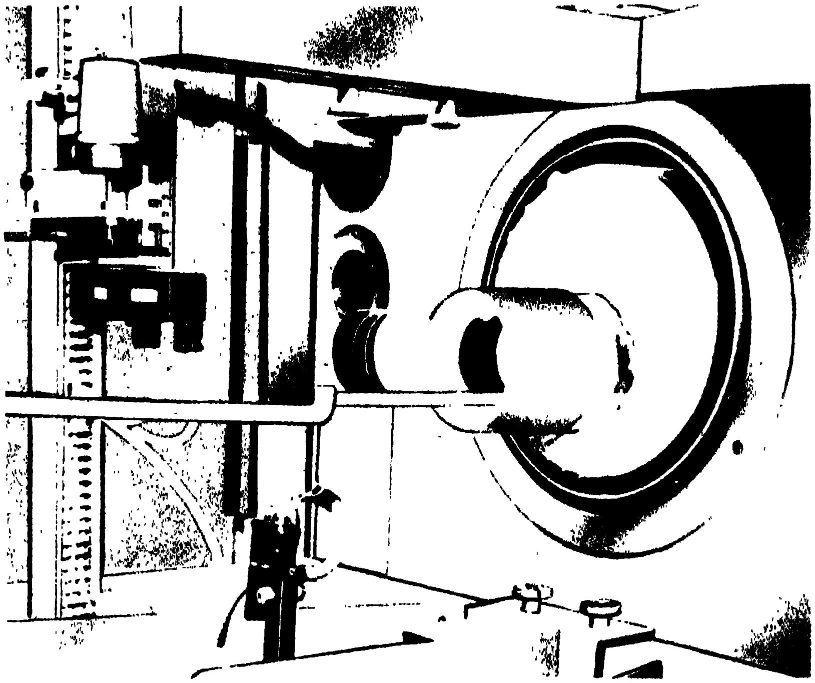

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Long-duration digital timer

THE solid-state long duration multirange timer described below uses three integrated circuits. The first one is the IC 555, the linear type of integrated circuit. You are already quite familiar with this IC, having used it in many projects which appeared in this column. The other two ICs are both CMOS digital IC 4017, which you have used in "IC Frequency Standard" (SCIENCE TODAY, June 1981, p. 59).

You might first ask—what are digital circuits? This can be probably best answered by contrasting digital circuits with linear circuits. In a linear circuit, a continuous variable input signal gives rise to a continuous variable output in a desired manner, which is related to the input variable by some mathematical expression. In a digital circuit, the input and output signals are assigned only two values: a so-called logic zero or low state, which is practically zero volt and a so-called logic one or high state, which is often some defined positive voltage. The output of a digital element can, in general, assume only one of these two levels in response to an input, or inputs, also having one of these two levels. The performance of a digital circuit for voltages in between these two levels is generally not required and thus not defined.

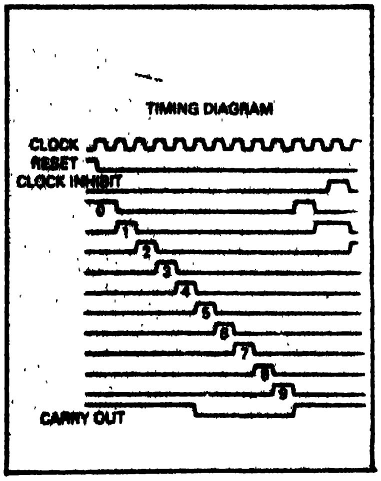
The common types of digital integrated circuits are RTL (resistor-transistor logic), DTL (diode-transistor logic), TTL (transistor-transistor logic), ECL (emitter-coupled logic) and COSMOS—abbreviated CMOS (complementary-symmetry metal oxide semiconductor). Each of these types offers its own particular advantages, compared to the other types, but all except CMOS have the following common disadvantages: 1) high quiescent current, 2) regulated power supply requirement, 3) low input impedance of the order of a few hundred ohms, and 4) poor noise immunity.

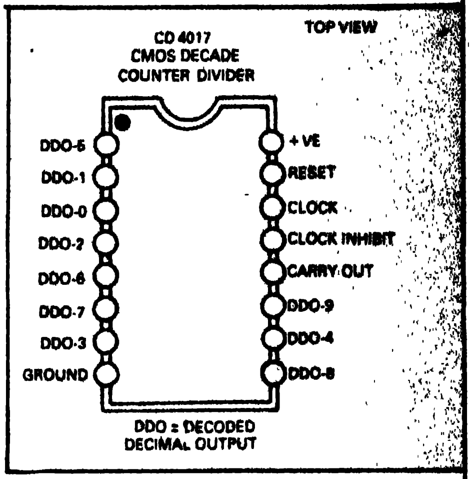
The CMOS digital integrated circuits, on the other hand, have the following unique properties: 1) negligible quiescent current 2) they can be operated from a wide range of supply voltage; regulated power supply not necessary 3) exceptionally high input impedance of the order of a million megohms 4) high noise immunity 5) output can virtually swing from zero to full positive voltage.

To understand the operation of this multirange timer, the circuit can be divided into three parts. The right side of the circuit is the step-down transformer with rectifier filter to provide about 15V DC for the operation of the device. The centre part is the two-stage decade counter-divider using two CMOS 4017 ICs and a Darlington pair configuration to drive the relay. The left part of the circuit is an

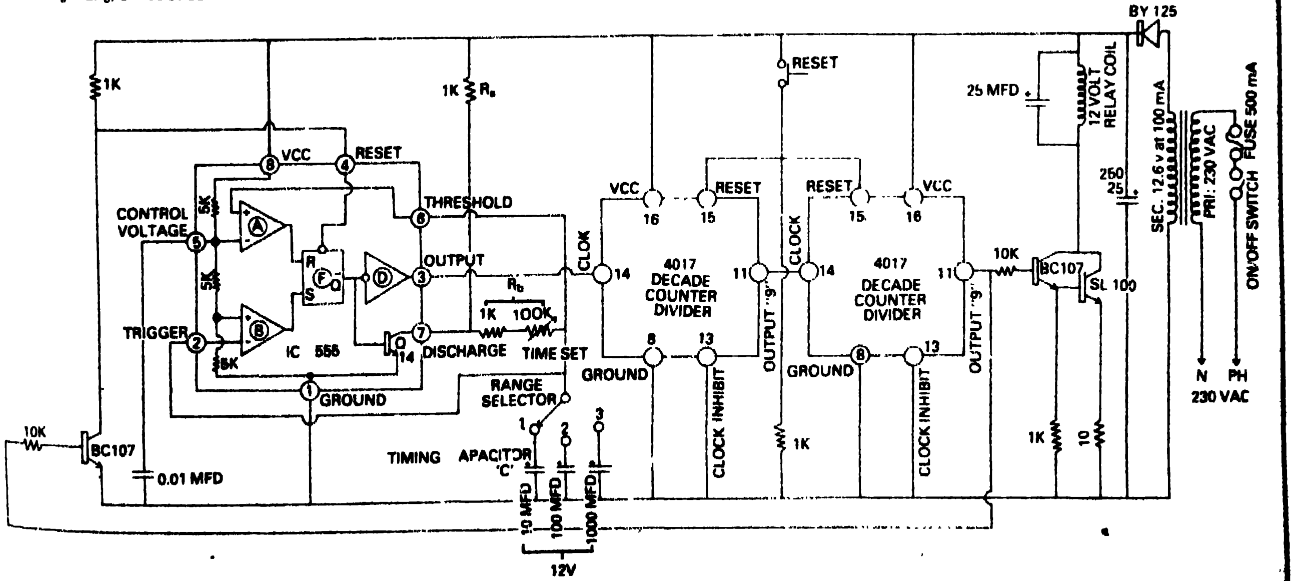
APPROXIMATE TIMINGS PROVIDED BY THE TIMER		
RANGE	TIME SET MIN	TIME SET MAX.
1 10 MFD	1.8 SEC.	2 MIN 30 SECS
2 100 MFD	18 SECS.	26 MINS
3 1000 MFD	3 MINS	4 HOURS, 20 MINS

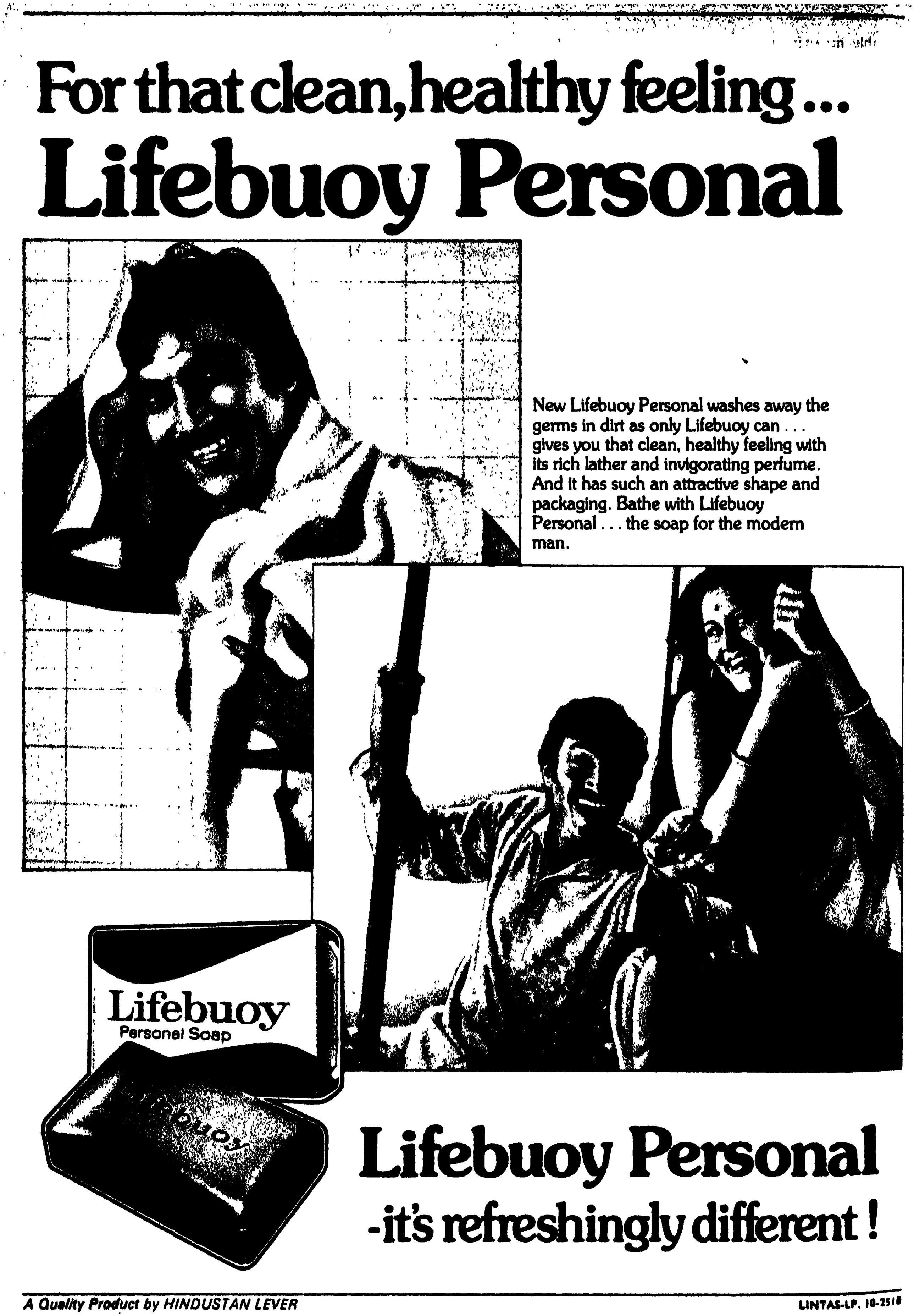
$T = 0.7 (R_a + 2R_b) C \times 90$ SECS.





DDO = DECODED DECIMAL OUTPUT





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astable multivibrator using IC 555.

The IC 555, used as an astable, that is, free-running multivibrator has its trigger terminal 2 connected directly to the threshold terminal 6. Thus, to start with, the timing capacitor, selected by the selector switch, has no charge over it. This triggers the lower comparator which, through the control flip-flop and inverting amplifier, drives the output high and simultaneously makes the discharging transistor Q14 non-conductive. This causes the capacitor to charge through the 1K resistor and 100K time-set potentiometer. When the capacitor charges to 2/3 Vcc, that is, the threshold level of the upper comparator, it resets the flip-flop, which in turn drives the output to its normal low state and brings the discharging transistor back to conduction. As the terminal No. 7 of the IC is now clamped to ground through the discharging transistor, the timing capacitor, instead of charging, starts discharging through the 100K potentiometer. The voltage across the capacitor gradually falls down. When the voltage falls to 1/3rd Vcc level, the lower comparator gets triggered and once again changes the state of the output and discharging transistors. This causes the capacitor to charge again. This completes one cycle and initiates the next.

The process continues, making the capacitor charge and discharge to 2/3 Vcc and 1/3 Vcc levels, respectively. The repetitive high and low going output provided by this astable stage is fed to the clock input terminal of the CMOS decade counter-divider IC 4017.

The first IC 4017 counts the number of pulses received and provides a single pulse, at its terminal No. 11, for every 10 pulses received at its clock input terminal No. 14. This divided-by-10 output provided by the first IC 4017 is fed to the clock input terminal of the second IC 4017. Thus, when the second IC 4017 receives the ninth pulse, that is, when the astable multivibrator goes through 90 astable operations, the terminal No. 11 provides a high output. This high output drives the Darlington pair amplifier stage to energise the relay and simultaneously clamps the reset terminal of the IC 555 to ground, thus making the astable multivibrator inoperative.

The timing duration provided by the above arrangement is equivalent to ninety cycles of astable operations of the first stage. When the timer goes through one operation, the next operation can be started by just pressing the reset push button.

This timer provides time durations from about a second to four hours. The chart alongside the circuit diagram will explain the durations provided by each range.

You will need:

Semiconductors

Integrated circuits: IC 555—1 No.; IC 4017—2 Nos.

Transistors: BC 107—2 Nos.; SL 100—1 No.

Diode: BY 125—1 No.

Capacitors

Ceramic or polyester: 0.01 mfd—1 No.

Electrolytic: 1000 mfd - 12V—1 No.; 250 mfd - 25V—1 No.; 100 mfd - 12V—1 No.; 10 mfd - 12V—1 No.

Resistors (all ½ watt type)

10K—2 Nos.; 1K—5 Nos.; 10 ohms—1 No.

Potentiometer: 100K wire-wound or carbon linear—1 No.

Switches: Normally open, pushbutton switch—1 No.; One pole, 3 way—1 No.; On/Off switch—1 No.

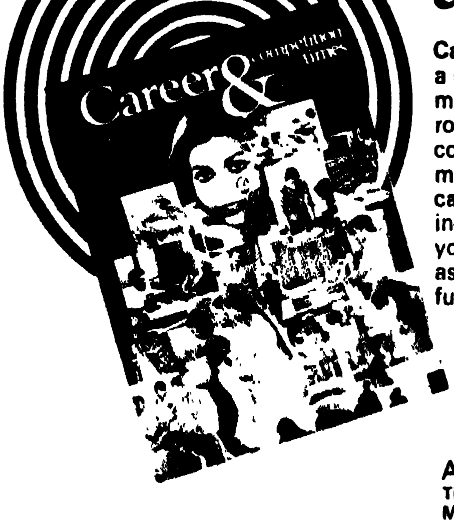
The approximate cost of the above electronic components in Bombay market is Rs 100.

Relay: 12V DC (Coil resistance more than 200 ohms) with two sets of changeover contacts.

Transformer: Pri: 230V AC. Sec: 12.6V AC at 100 mA—1 No.

Misc. Mains cord, solder, wires, screws, suitable enclosure, IC experimenter's veroboard, knobs, fuse 500 mA with holder.

ANIL V. BORKAR



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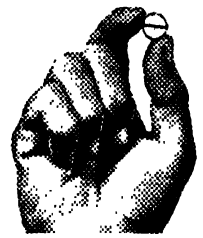

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AWARDS AND APPOINTMENTS

INSA Awards

THE Indian National Science Academy (INSA) at its 47th Annual General Meeting at New Delhi last month announced the following awards:

The Srinivasa Ramanujan Medal for 1982 to Prof. S. Chowla, FNA, Department of Mathematics, McAllister Building, Pennsylvania State University, USA, for his outstanding contributions to Number Theory; the Shanti Swarup Bhatnagar Medal (1982) to Prof. T. R. Anantharaman, FNA, Professor of Metallurgy, Banaras Hindu University, Varanasi, for his outstanding contributions to physical metallurgy, especially in metallic glasses and similar areas; the Silver Jubilee Commemoration Medal (1982) to Dr. V. S. Mathur, Senior Scientist, Indian Agricultural Research Institute, New Delhi, for his outstanding contributions to improvement of wheat varieties with high yield potential and resistance to diseases; the Prof. T. R. Seshadri Seventieth Birthday Commemoration Medal (1982) to Dr. Sukh Dev, FNA, Director, Malti-Chem Research Centre, Baroda, for his outstanding contributions to chemistry and chemical technology; the Vishwakarma Medal (1982) to Dr. Nitya Nand, FNA, Director, Central Drug Research Institute, Lucknow, for his outstanding contributions to the development of indigenous pharmaceutical industry.

The INSA Endowment Lecture—Prof. K. Rangadhama Rao Memorial Lecture (1981) has been awarded to Prof. K. Narahari Rao of the Department of Physics, Ohio State University, USA for his outstanding contributions in spectroscopy. The Lecture will be delivered under the auspices of the INSA Local Chapter, Madras, at the Indian Institute of Technology, Madras, in December 1981.

The INSA Endowment Lecture (1981), endowed by Dr. G. P. Chatterjee and Mrs. Suniti Chatterjee, has been awarded to Prof. S. C. Bhattacharyya, FNA, Director, Bose Institute, Calcutta, for his outstanding contributions in organic chemistry.

K. S. Krishnan Memorial Lectureship

THE Kariamanikkam Srinivasa Krishnan Memorial Lectureship (1981) has been awarded to Prof. Devendra Lal, Director of the Physical Research Laboratory, Ahmedabad.

Instituted by the INSA in 1965 in memory of the late Dr. K. S. Krishnan, a Distinguished Scientist and Fellow of the Academy, the Lectureship is awarded to an eminent scientist for outstanding contributions to any branch of natural science coming within the purview of the Academy. The Lectureship is awarded every six years and carries a cash award of Rs. 1,000.

The award to Prof. Lal is in recognition of his outstanding contribution to isotopic composition of elements as induced by cosmic radiations and studies on meteorite and lunar samples.

CFTRI Director

MR. S. K. Majumder, Deputy Director of the Central Food Technological Research Institute, Mysore, has taken over as Director from Mr. C. P. Natarajan, who has retired.

Hari Om Ashram Trust Award

THE following scientists have been selected by the University Grants Commission for the Hari Om Ashram Trust Awards for 1977 and 1978: Prof. R. B. Srikantam, Dr. V. G. Bhide, Dr. L. K. Doraiswamy, Dr. M. K. Vainu Bappu, Prof. M. S. Narasimhan, Prof. V. S. R. Rao, Prof. A. N. Radhakrishna, Dr. S. Sriramachari and Prof. K. Ramachandran.

The awards carry a cash prize of Rs. 10,000 each.

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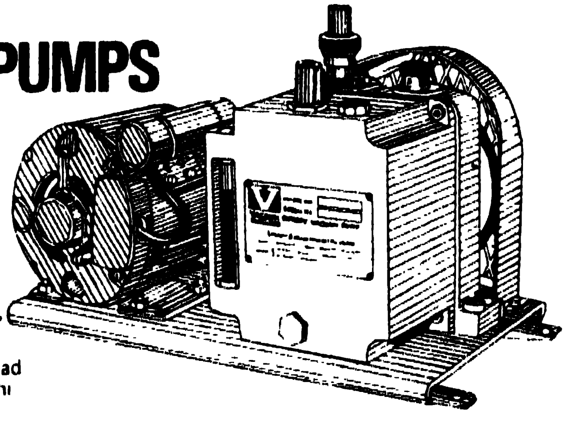

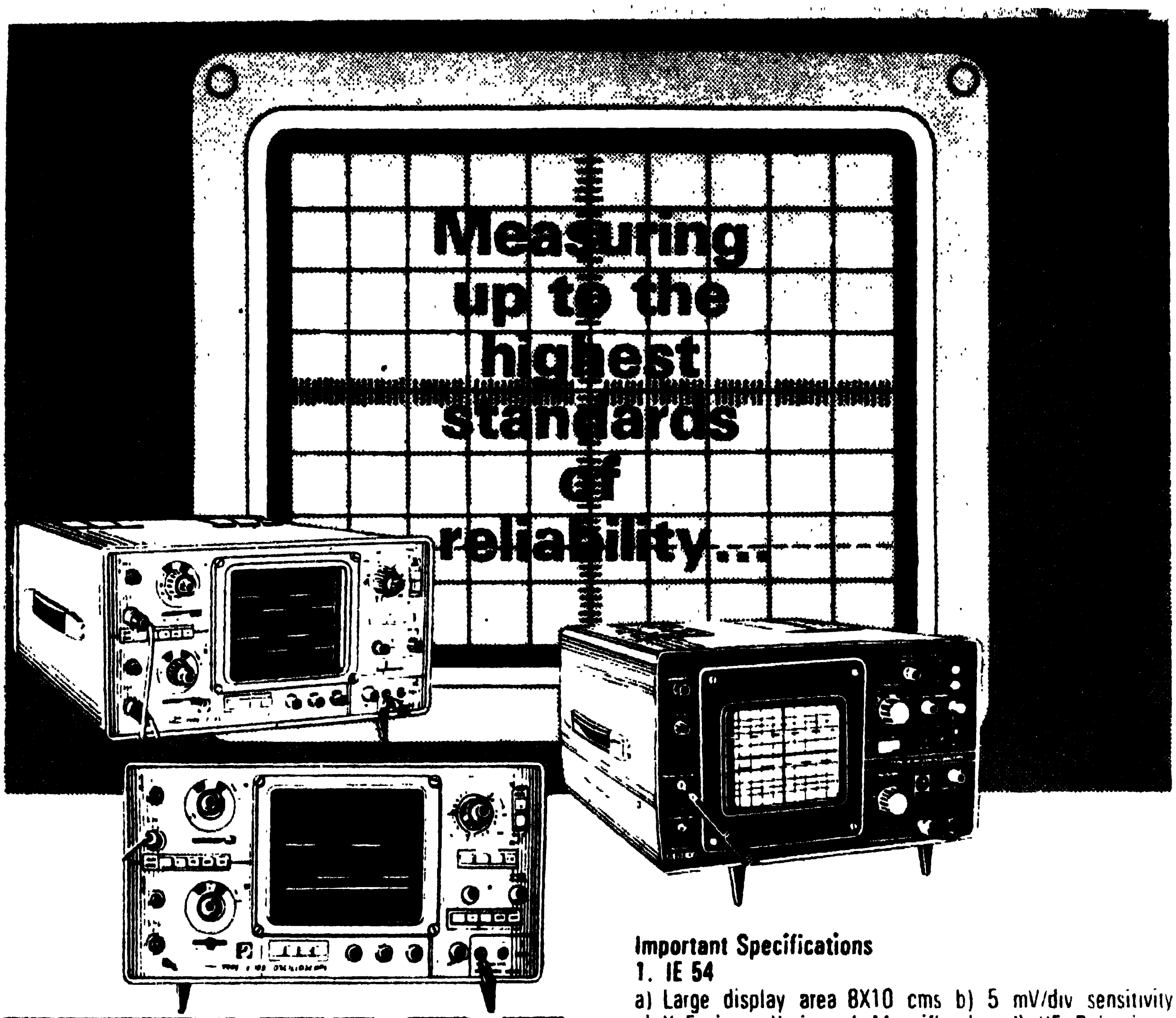

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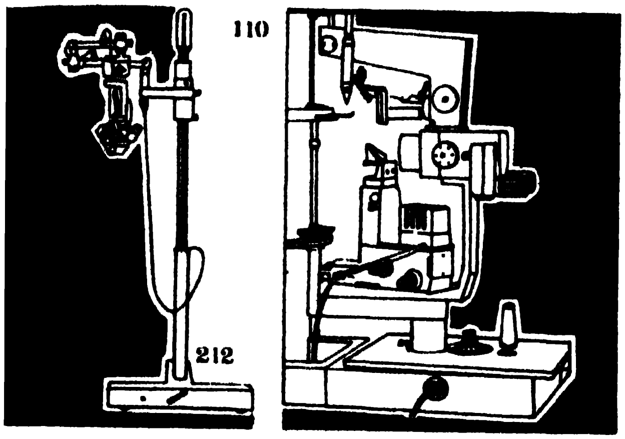

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MEETINGS CALENDAR

December

2-9: Theory of programming and design of algorithms, workshop on foundations of software technology, Indian Institute of Science, Bangalore (Dr. R. K. Shyamsundar, NCSDCT, Tata Institute of Fundamental Research, Homi Bhabha Road, Bombay 400 005)

17-19: Seed physiology and biochemistry, national symposium, Lucknow University, Lucknow (Dr. P. K. Agrawal, Convenor, Symposium on Seed Physiology and Biochemistry, Division of Seed Technology, Indian Agricultural Research Institute, New Delhi 110 012)

21-23: Mass spectrometry—progress in research applications and instrumentation, national symp., BARC, Bombay, India (S. Krishnan, Sec., symposium committee, Heavy water divn., Engg. Hall No. 2, BARC, Trombay, Bombay 400 085)

21-24: Rehabilitation of structures, int.symp., Indian Institutes of Technology, Bombay (Mr. R.N. Raikar, Hon secretary, Maharashtra India Chapter of Concrete Institute, 1008/9, Raheja Centre, Nariman Point, Bombay 400 021)

22-24: Physics of semiconductors, seminar, BARC, Bombay (Dr.S.Guha, Tata Institute of Fundamental Research, Bombay 400 005)

27-30: Quality and reliability, national conf., Indian Institute of Technology, Bombay (Prof. M.N. Gopalan, Organising secretary, National conference on quality and reliability-1981, Department of Mathematics, Indian Institute of Technology, Powai, Bombay 400 076)

28-1: Silver jubilee physics symposium, BARC, Trombay, Bombay (C. L. Thapar, Convenor, Silver Jubilee Physics Symposium, Room No. 45, CIRUS, BARC, Trombay, Bombay 400 085)

28 Dec.—2 Jan.: Teaching of quantum mechanics including its philosophical implications, regional conference, Delhi University, Delhi. (Prof. L. S. Kothari and Prof. A. N. Mitra, Dept. of Physics, Delhi University, Delhi 110 007)

29-30: Microwaves and communication, int. symp., IIT, Kharagpur, India (Prof. B. Chatterjee, Chairman, Organising committee, International symposium on microwaves and communication, Department of Electrical and Communication Engineering, Indian Institute of Technology, Kharagpur 721302 West Bengal)

January 1982

IETE: The Institution of Electronics and Telecommunication Engineers) annual general meeting, technical convention and exhibition, Delhi, India (IETE, 2, Institutional Area, Lodi Road, New Delhi 110 003). (Dates not intimated)

(8 days): International science exhibition for children organised by All India Science Teachers' Association, New Delhi, India (Prof. U. N. Wanchoo, Chairman, All India Science Teachers' Association, A-55 Ashok Vihar-II, Delhi 110 052) (Dates not intimated)

6-8: Cellular control mechanisms, symposium, BARC, Bombay (Dr. G. P. Phondke, Head, RBOH Section, Medical Division, Bhabha Atomic Research Centre, Bombay 400 085)

8-15: Nutrition and the development of the child, int. workshop, Baroda (Department of Biochemistry, M.S. University, Baroda).

11-14: Baryon non-conservation, int. colloquium, TIFR, Bombay (Dr. V. S. Narasimham, Tata Institute of Fundamental Research, Bombay 400 005)

17-22: Indian standards, 19th convention, Madras (J. K. Bhavnani, Organising Secretary, Nineteenth Indian Standards Convention, Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110 002)

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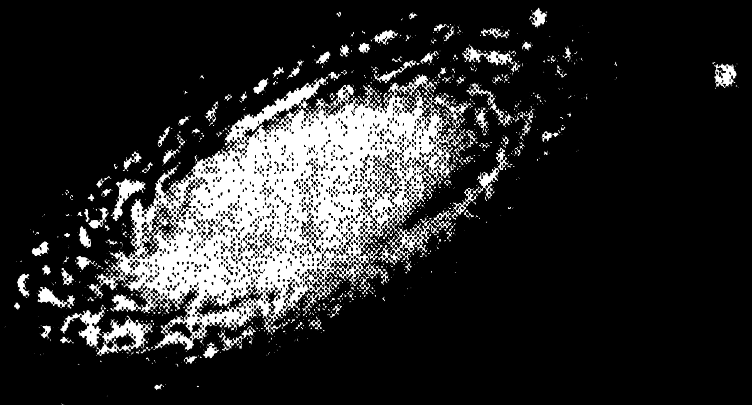

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IF...

...the carbon nucleus were slightly different

DURING the mid-1950s a Cambridge theoretician walked into Caltech's Kellogg Radiation Laboratory saying "Look for an excited state of the carbon nucleus". Although he gave some indication of the energy level at which he expected to find this state, the first reaction of the hard headed experimentalists was to throw this crazy Englishman out. Nevertheless, one physicist took the suggestion seriously and looked for the excited state and he found it. The Englishman was Fred Hoyle and the Kellogg physicist was William Fowler and this encounter was the beginning of their long partnership which led to many interesting results in astrophysics.

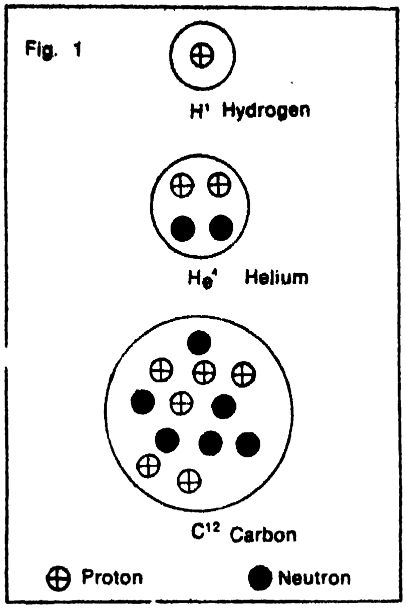
What prompted Hoyle to come up with the above prediction about the carbon nucleus? Hoyle's reasoning was simple yet far reaching; for it led to the conclusion that if such an excited state of the carbon nucleus did not exist, life as we know it would not be possible in the universe!

Why is a small detail in the construction of a particular nucleus so important to our existence? To understand the answer to this question we have to go back to the problem of the origin of elements. The smallest unit in which an element occurs in nature is the atom which consists of the central nucleus carrying positively charged particles, the protons and electrically uncharged particles called the neutrons (Fig. 1), surrounded by a host of negatively charged particles called electrons orbiting the nucleus. How the protons and neutrons are distributed within the nucleus determines its energy level. The nucleus is usually in the state of lowest energy level called the ground state, while it can also exist in states of higher energy called the excited states. The key to the understanding of the origin of elements lies in knowing how nuclei are formed and with what energies.

Astrophysicists believe that the universe began with only hydrogen, the simplest element, and that the heavier elements were built up progressively through the process of thermonuclear fusion. The fusion process consists of adding protons or neutrons or even whole nuclei to an existing nucleus to make it into a bigger one. The hydrogen nucleus has only one proton and no neutron. By bringing four such nuclei together in a fusion process a nucleus of helium is formed. This change is shown symbolically by the following:

$$4H^1 \rightarrow He^4$$

Fig. 1



(The superscript on top of the element symbol denotes the total number of particles in the nucleus; the helium nucleus has four particles, two protons and two neutrons.)

Fusion processes require high temperature and pressure which are typically found in the deep interiors of stars. The Sun for example, is currently processing hydrogen into helium. In this process lot of energy is released which is responsible for keeping the Sun shining.

It is found that the helium nucleus is a stable unit and it is useful as a building block towards the fusion of heavier nuclei. Thus from a carbon nucleus (C^{12}) we can produce an oxygen nucleus (O^{16}) by adding one He^4:

$$C^{12} + He^4 \rightarrow O^{16}$$

By successive addition of H_e^4 we can similarly produce heavier nuclei like Neon (Ne^{20}), Magnesium (Mg^{24}), Silicon (Si^{28}) and so on.

However, nuclear astrophysicists faced a severe difficulty right in the beginning. The above process should start off by bringing two He^4 nuclei together:

$$He^4 + He^4 \rightarrow Be^8$$

The resulting nucleus of beryllium is, however, unstable. As soon as it is formed it breaks apart into the two helium nuclei.

This is where we encounter our first "if". What would have happened if Be^8 were a stable nucleus? If Be^8 were stable, all helium in the star would have been consumed rapidly in the above reaction and in the following reactions building bigger nuclei:

$$Be^8 \rightarrow C^{12} \rightarrow O^{16} \rightarrow \ldots.$$

However, the rapidity with which energy is released in such reactions would have made the star explode as a supernova long before the above chain progressed very far! In fact Hoyle calculated that the process would terminate in stellar explosion by the time carbon was formed. Thus the universe would have had vast quantities of carbon, but very little of the heavier elements. Elements like sulphur, silicon, iron, etc would have not existed. The Sun would have had a massive graphite planet very close to it, in the place now occupied by Mercury.

But Be^8 is unstable! So how do we start the chain of nuclei building? Hoyle calculated that if we cannot use Be^8 as the stepping stone towards higher nuclei, we can simply bypass it by trying to build C^{12} by bringing *three* He^4 nuclei together:

$$3He^4 \rightarrow C^{12}$$

However, bringing three nuclei (instead of two) together is not easy and the process described above would have a low probability of happening. Again, Hoyle was faced with the result that very little carbon would be produced unless. . Unless a resonant reaction is possible. In a resonant reaction the energy of the product nucleus is slightly more than the energy of each component nucleus when at rest. Resonance is a phenomenon which occurs elsewhere in physics. If a vibrating system is subjected to a periodic force whose frequency matches the natural frequency of the system, the system responds by vibrating with very large amplitude. To avoid such large resonant vibrations and consequent damage soldiers marching across a suspension bridge are advised to break steps (SCIENCE TODAY December 1980 p. 16). If a resonant reaction occurs between helium and carbon, it would proceed very fast and would compensate for the fact that the chance of three He^4 coming together is small.

For such a resonant reaction to occur the carbon nucleus must have an energy level at the appropriate place. Hoyle's calculations suggested that an excited state of carbon will be required. If such a state did not exist, very little carbon would be produced, still less oxygen and hence there would be no life as we know it. But, as we saw in the beginning this 'if' also is avoided. An appropriate excited state of C^{12} does exist!

As a postscript Hoyle mentions that no such excited state exists for O^{16}. For, if it did, the Universe would have produced mostly oxygen and no carbon, thus again jeopardising life! These arguments show how little things (apparently!) seem to matter a good deal in the overall scheme of the universe.

JAYANT V. NARLIKAR

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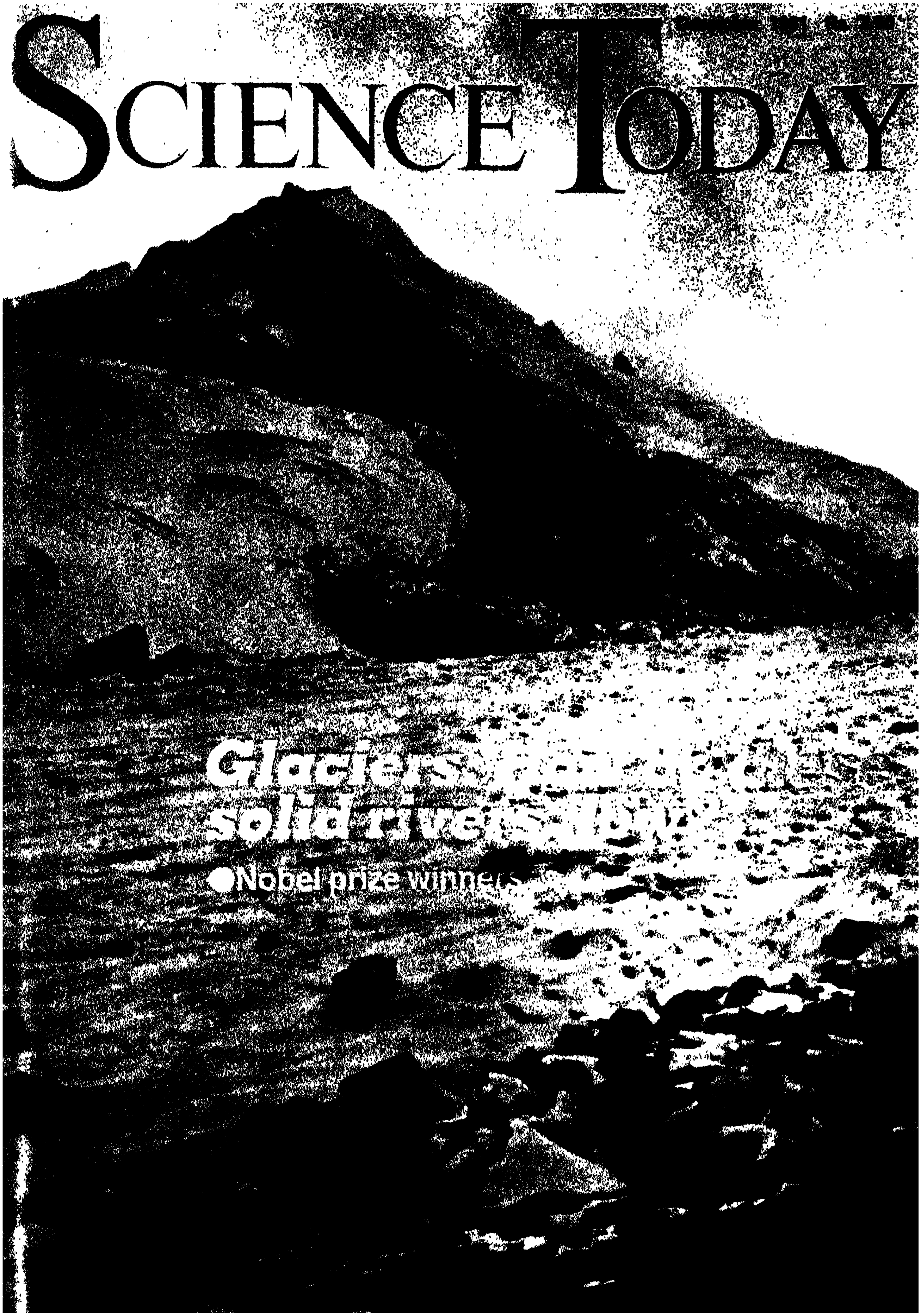

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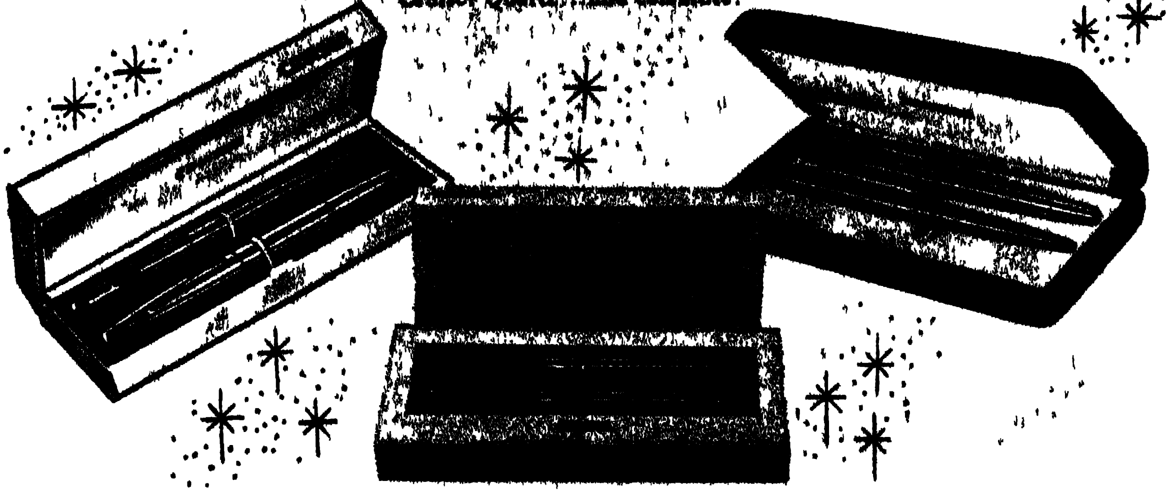

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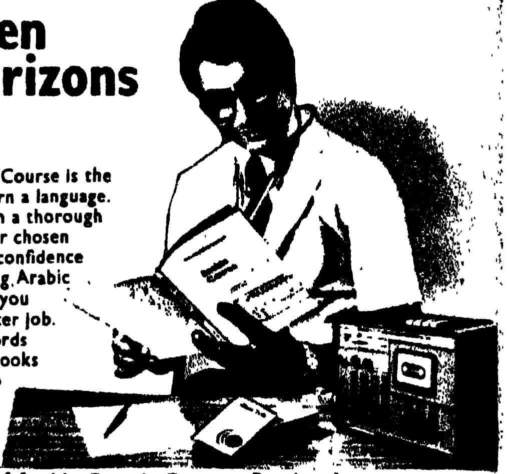

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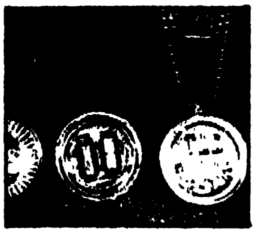

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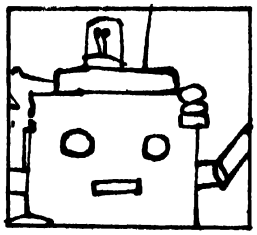

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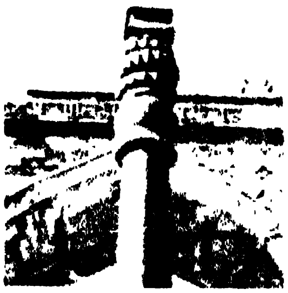
LETTERS

THE DELHI IRON PILLAR

IN "Cultural Contours of Iron in Ancient India" (September 1981), B. V. Subbarayappa explains that the excellent corrosion resistance of the Delhi iron pillar is due to its large phosphorus content and near absence of sulphur and manganese. While I am nearly in agreement with the author on this aspect, I do not know of any forging technique which will give a protective magnetite coating on iron.

Recent studies on iron-based amorphous alloys ("When Metals Turn Glassy", May 1981) which contain proportions of phosphorus and carbon have shown that phosphorus-carbon imparts good corrosion resistance to the alloy, provided some protective element like chromium or molybdenum is also present. Interestingly, manganese, in small quantities, increases the corrosion of these alloys. Phosphorus induces fast dissolution of the alloy in aggressive environments, leading to an enrichment of the protective element—like chromium and molybdenum—at the metal surface and the rapid formation of a highly protective passive layer. The good corrosion resistance of such alloys is thus attributed to the presence of an amorphous surface film which contains up to 95 per cent of trivalent chromium ions. These findings raise the following questions regarding the corrosion resistance of the Delhi pillar. Does the pillar contain any protective element like chromium, molybdenum or titanium? Is the surface film on the pillar a magnetic iron oxide or an amorphous film containing a protective species? Is it possible that the pillar, before installation, was given a pretreatment in which it was allowed to corrode fast in a moist atmosphere or in an aqueous medium so that the protective surface film was formed?



I feel that the first two questions can be answered by a careful analysis of the surface film on the pillar. Modern surface analysis techniques like ESCA/Auger (available at Delhi) can be used to get the exact chemical composition as well as the type of bonding existing at the surface.

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Dr Subbarayappa writes *According to the several chemical analyses reported in the* NML Technical Journal *(5, 1, 1963), the pillar does not contain chromium, molybdenum or titanium. This special issue on the Delhi iron pillar (published by the National Metallurgical Laboratory, Jamshedpur) also has references to the effect that (i) the scale on the pillar has approximately 80 per cent of an oxide of iron having the properties of the solid solution phase mixture of* FeO *and* Fe_2O_3, *and (ii) rust scrapings and scales have magnetic portion varying from 80 per cent to 65.5 per cent.*

Besides these, various aspects of the corrosion resistance of the pillar have been dealt with in this journal. All this is not to suggest that the problem of corrosion resistance of the pillar has been solved satisfactorily. There are divergent views expressed even in the above journal. And since there is the need to re-assess the phenomenon, it would be good if Dr. Namboodhiri and his colleagues at BHU come forward and investigate it.

THE SCRIPTURES OR CORRUPTION?

MR P N HAKSAR (Letters, September 1981) has entirely missed the main point in my letter (June 1981) that the regard for scriptures need not come in the way of one's attainments and progress. That was my main purpose in mentioning George Sudarshan, Oppenheimer and the French and German scientists.

The reasons for our backwardness today are undoubtedly the rampant corruption, nepotism, greed for pelf and power (even in our scientific institutions), and the faulty, lopsided planning which has not only failed to check the population explosion, unemployment, illiteracy and energy-famine, but is also causing widespread air and water pollution, denudation of forests, ecological disasters, etc. Ignoring all these factors (I presume that Mr. Haksar does not attribute *these* to our scriptures) and singling out our scriptures for blame is being over-simplistic in one's diagnosis.

T. M. S. RAO
6/1 Bajajwadi
Bombay 400 054

ALTHOUGH Mr. Haksar was not at all wrong in blaming the scriptures, he could have preferred our politicians for castigation. It is their activities, from the level of the party worker to the cabinet member, that have far-reaching effects on public life and are mainly responsible for the backwardness of our country.

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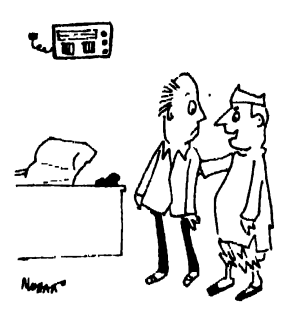
Qrs. No. B—99
Sector 14, Rourkela



Excuse me, but before helping you out, our ancient tradition of questioning and introspection compels me to ask this. How much do I get in cash?

ANDROSTENOL AND SEX AROUSAL

IT is rather incorrect to say that androstenol is found only in males and serves as sex-attractant for women (Scent signals in humans", January, 1981, p. 56) because Ann E. Kingsbury and B. W. L. Brooksbank of the Institute of Neurology, London, identified this pheromone in the axillary sweat of both sexes and noted its higher concentration in women (*Hormone Research* 9 254, 1978). Several investigators claim that it elicits sex arousal in men as well as in women. However, Patricia A. McCollough, John W. Owen and Edward L. Pollak of the West Chester State College, Pennsylvania, in a current research on the problem, have observed that the male's sexual scores exceeded the female's after smelling the compound (*Ethology and Sociobiology*, in press).

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Science fiction films: How much science? How much fiction?

WHAT purpose does fiction serve? Howsoever we may wish to glorify fiction by saying that it is supposed to be thought-provoking, that it has a worldy moral or that it carries a profound message, the fact remains that it is basically meant to provide diversion to the human mind. Folk tales, fairy stories, mythological sagas served this purpose in the past. To these were added historical novels and adventure yarns. In the twentieth century, in the so-called age of science, the list has been further augmented by the addition of science fiction.

"The Message of Science Fiction: Prophetic or Profane?" was the topic of a public discussion held in 1975 at the California Institute of Technology between Ray Bradbury and Fred Hoyle. I recall that both speakers agreed on what constitutes good science fiction and what is bad science fiction. They did not agree so much on how successful science fiction had been (and was likely to be) as a guiding light to society. Bradbury took the optimistic view and Hoyle the pessimistic.

Bradbury was of course highlighting good science fiction and extolling how successful it had been in "seeing the future" while Hoyle was bemoaning the fact that the bulk of science fiction was bad or trivial and yet commercially successful. Although the discussion related to science fiction literature, many of the points apply, with even greater force, to science fiction in the visual form.

With the advent of the cinema and later the television, science fiction found visual expression. As in literature, here also the main criterion of success has been how well the piece in question could amuse, divert and attract the viewer's mind. To put it more bluntly, the measure of success of a science fiction film or a TV series is expressed in terms of the box office, audience rating, advertising revenue, etc. It is against this background that we should assess science fiction films.

No doubt, the richness of the fare-served and its obvious popularity is impressive. Starting from movies based on such classics as *The War of the Worlds* (H. G. Wells), *Journey to the Centre of the Earth* (Jules Verne) *The Lost Continent* (Conon Doyle) to modern works like *Star Wars* and *The Andromeda Strain* we have serials like *Dr. Who* which has been running for over two decades with the fourth actor recently stepping into the role of *Dr. Who*. There are also TV series like *Star Trek* with many adventure involving the same set of characters. Judging by the successes enjoyed by these creations, we get the first impression that science fiction has really caught on. But... just how much science is there in these works?

To the popular mind, science fiction is computers with flashing consols, scientists in white coats or other distinctive apparel, space ships to and from the 'outer' space, astronauts in gas masks, strange weapons of destruction and, of course, those sinister aliens. Is this real science fiction? If not, what is? Where does one draw the line between futuristic predictions of how science will shape society and *vice versa* and someone's whimsical fantasies? Personal assessments would vary even among scientists. Anyway, here I give my own assessment of some of the better-known science fiction films, old and new.

Let us first consider movies which are good, clean family entertainment in which special effects predominate and which contain all the above ingredients in plenty. *Star Wars* and its sequel *The Empire Strikes Back* are examples of this kind. These are *not* science fiction. Rather, these two, in particular, are old westerns in a new garb, horses replaced by strange beasts, stage coaches by space ships, the baddies by sinister aliens and so on... One wonders whether supercivilisations which draw energy from stars and engage in interstellar travel would be subject to the same emotional stresses as we mortals are! Can we travel faster than light? Why do space ships supposedly travelling under zero gravity environment bank and fall as they manoeuvre through space? Why are their computers so bulky when in the last two decades we have seen them grow more and more compact? Never mind. Dismiss such scientific doubts and enjoy the film. Do not delude yourself that you are watching science fiction.

Science fiction and fantasy

Turning to the other extreme, let us look at *2001: A Space Odyssey* and *Zardoz*. Both are remarkable for their special effects, those in *2001* being more impressive. Both are examples of science fiction which takes us beyond our immediate past and future and which makes us pause and ponder.

2001 portrays the evolution of man from the wild killer ape to the present 'civilised' state and also looks towards his fantastic future (symbolised by 'angels'). A monolith of dimensions in the ratio 1^3: 2^2: 3^3 (suggestive of a Pythagorean concept of perfection?) plays the key role in elevating man from the ape to higher echelons of life. The haunting tune from the slab, shrill but musical, was borrowed by the BBC as a signature tune for its telecasts of the Apollo 11 moon-landing mission. One wonders whether a pop or a rock-based tune would have come out as profound. The special effects too were impressive, especially the astronauts moving about inside (and outside) the space ship under zero gravity. The 'rebirth' sequence towards the end is also very impressive although it is more a fantasy than science.

By comparison, *Zardoz* has more fantasy. It portrays the evil of immortality. Set in the year AD 2293, it describes a small elite group which lives in a 'vortex' apart from the underprivileged 'brutals'. The former have achieved effective immortality since their scientists managed to leave the key to their death in the central tabernacle with many safeguards to prevent access. The brutals have a chosen few—chosen by their god Zardoz—who exterminate the rest under command from him. 'Zardoz', a deformation of Baum's *Wizard of Oz*, is like the old wizard—a humbug not really possessed of superpowers. He is in fact from the vortex and his secret is discovered by 'Zed', a more than curious brutal. Zed enters the large rock head of Zardoz, kills the god and comes to the vortex. He is subjected to scientific analysis there but in the process he becomes wise to many facts. He finally enters the tabernacle, discovers the secret of death and releases the elite colony from the pains of immortality.

If eating, drinking and merry-making are all that is left to do, would immortality be a boon or a terrible bore? Although we are a long way off from the situation depicted in *Zardoz*, the problem can be visualised even today. Would science and technology widen the gap-between the 'haves' and the 'have-nots'? Will the gap reach the terrible form shown in the film? If no challenges are left, would living be worthwhile?

Films like *2001* and *Zardoz* are thought-provoking, though not everybody's cup of tea. To be box office hits, films like these have to have a sustained plot and, special effects. *2001* is more popular because it is more successful than *Zardoz* on both these fronts. However, films in this category are few and far between.

The middle majority

Between the juvenile but successful *Star Wars* and the philosophical but successful *2001* lies the more typical middle level science fiction film. In this type of films, we are concerned with the immediate past or future. The scientists are faced with a problem of their own creation (research getting out of hand, the mad scientist, Frankenstein, and so on) or they are called upon to save humanity from some alien danger. Depending on the director and the 'science' he has to portray, such a film can either degenerate into a mediocre thriller or turn out to be a sophisticated suspense film. *The Andromeda Strain* is a film in this middle category which manages to rise above the average level.

This film is about an alien life form which is brought to the Earth by a returning space probe. The life form is obviously hostile to earthlings, for, falling on a New Mexico village, it swiftly destroys most of its 68 inhabitants. Only two are spared, an old man and a six-month-old baby. Why and how was the death brought about? Would the danger spread? How do we control the alien 'thing' from growing? What is it, anyway? And why were two humans immune to it?

It is up to the scientists to find the answers to these questions and that too in a very short time. A team of top class scientists is chosen (including a Nobel laureate, of course). In fact, the team has been selected and is standing by in case such an emergency arose. And they are to work in a superlab designed to meet just such catastrophic situations, a laboratory deep underground with each lower level increasingly decontaminated. The process of decontamination, the working of an experiment by electronic hands, the precautions in case the scientists lose control over their experiments...all are very well shown. We also catch glimpses of pompous and self-centred (but powerful) politicians and dedicated but narrow-minded scientists with all their brilliance and whimsicality. We are shown in a brief episode the mixed reactions of the superscientists when they suspect that this superlab, built at their behest at a cost of billions of dollars, might also be used for biological warfare.

Astronauts in spaceship from *2001: A Space Odyssey*

With so much of the scientific atmosphere and the aura of superior technology, it is ironical to see in the anti-climax (which is supposedly the climax) that to save the superlab from self-destruction, the one person holding the key (which can stop it all!) has to climb a vertical ladder up several metres to find the appropriate key hole. So ultimately it is man's ape-ancestry that saved the situation. Did the movie have to end like that?

As Ray Bradbury argued in the discussion mentioned at the beginning, we *are* living in the age of science fiction. Our grandfathers would have considered today's science and technology pure science fiction in their time. The miracle chip, the sophisticated weaponry, the advances in medicine...are they not incredible enough to justify the oftquoted remark, 'Truth is stranger than fiction'? Even on the adventure front, the rescue of the Apollo 13 astronauts from their lunar mission when power failed provided a more powerful suspense drama than most science fiction films have created. Surely a generation that witnessed this drama (live on TV in many countries) deserves more scientific climaxes in their films and novels than the ending in *The Andromeda Strain.*

Science fiction on TV

With a few exceptions, TV science fiction series (like *Star Trek*) rely more on adventure than on science. To devise a good science fiction serial with several episodes is no easy task. Yet, I was fortunate to see two serials, *A for Andromeda* and *Andromeda Breakthrough* (science by Fred Hoyle, script by John Eliot), both shown on the BBC in the mid-sixties.

More than 20 years ago, Cocconi and Morrison made the suggestion that it was feasible to search for extraterrestrial intelligence. Frank Drake had a small project to look for intelligent radio signals from outer space. The Jodrell Bank had a big radio telescope in operation while others were being built in the USA and Australia. It was against this background that *A for Andromeda* was written. The main plot is about a new radio telescope in Britain which receives intelligent signals from abroad—that is, from outer space. The signals are decoded; they contain the blueprint for a supercomputer the like of which was never even imagined. The computer is built. Again, aided by the outside code and the computer, the scientists 'build' a life form. It is a one-eyed monster promptly named 'Cyclops'. The scientists, especially biologists, are tempted to go further, for the computer is willing and capable of producing higher life forms. 'Stop. Proceed no further. What may come out could be an alien agent'—this was the advice from Fleming, the scientist who had originally been an enthusiastic supporter of the whole project. But he is overruled. The next creature is apparently not sinister. Instead, it turned out to be a charming girl (played by Julie Christie before she became famous). Fleming was suspicious. Was Andromeda, as the girl was named, really an alien agent? Thereby hangs the tale. And the computer? Fleming suspects its intentions but is assured that it can always be switched off if it turns hostile. But can it be? The scientists are in for a surprise....

Hoyle's *Black Cloud* was a novel written in the late fifties and was an excellent example of good science with speculative extrapolations woven into a nice plot. It is a pity it has not made its way onto the screen. In the novel, we have an interstellar cloud possessing life and intelligence. A number of scientific speculations in this novel have been successively verified. Radio and microwave techniques have shown the existence of complex organic molecules in the interstellar space. Giant molecular clouds between stars have been discovered. Maybe even intelligence will one day be discovered in such clouds!

From specific examples, I now come to generalities. What do I consider essential in a good science fiction movie (or TV series/serial)? To me it is axiomatic that science should be an essential component of science fiction. How much science and in what form may be indicated by the following range of possibilities: (a) the application of a scientific principle leading to unusual circumstances; (b) an exploration of what we know of science to situations vastly different from those we encounter on the Earth; (c) a piece of scientific research going beyond control and leading to catastrophes; (d) long-term forecasts of the present state and the march of science and technology and their impact on society; and (e) speculations of extraterrestrial intelligence that are not inconsistent with what we know about nature.

If we are to equip ourselves for living in the age of science, we should know what science is, what it stands for and what are its implications. A straight-forward discussion of these issues may be too drab or unpalatable to the layman. Science fiction, in my opinion, should have the role of a sugar-coated pill: attractive, at the same time, useful.

These considerations may explain why I do not consider *Star Wars* a science fiction movie while I regard some of the movies based on the classics of Wells or Verne as good examples of science fiction. *The War of the Worlds* envisages susceptibility of powerful aliens to our terrestrial bacteria. A single scientific concept like this is worth more than a host of robots, weird space ships and flashing computer panels. The prophetic element in the *Journey to the Moon* described by Verne in the last century was vindicated by Apollo 11 landing on the Moon. That good writers of science fiction have been successful in catching glimpses of the future was also shown by the example of communications satellites first thought about by the science fiction writer Arthur C. Clarke.

It is, however, too easy to jump from speculative extrapolations of known science to pure fantasy. I hold no brief for the latter and feel dismayed when it is passed off as science fiction. Even *2001* suffers from this defect towards its end.

Visual medium is a powerful tool for depicting science fiction. Modern technology, coupled with human ingenuity, has shown how special effects can be used to communicate fantastic ideas. However, as with other movies, the movies in this field are made primarily from box office considerations. There *Sholay* rules, not *Aparajito* or *Shataranj ke Khiladi*. But chances are we will see more of movies like *Star Wars* or *Superman* than movies like *2001*.

To sum up then, in spite of the many advantages the visual medium has over the written word, only some selected movies have capitalised on them and given us authentic science fiction. The rest are scientifically trivial, at best good fun and at worst a waste of time.

JAYANT V. NARLIKAR

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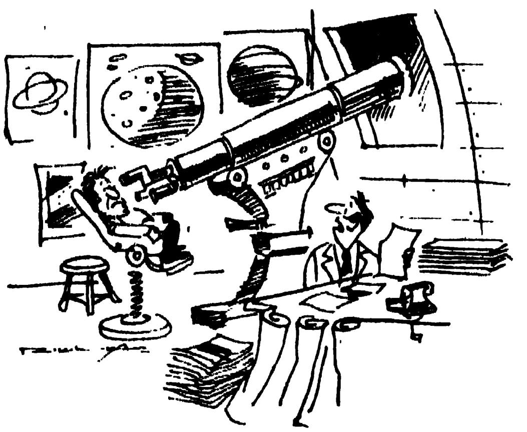
This World of Science!

By R. K. Laxman



"A note from the foundation, sir— Conditions on Earth no more permit studying conditions on Mars and Venus! Sorry, no funds from now on."

"Don't behave like an illiterate! You very well know it's extinct!"

"I returned from abroad giving up a good job to do social work among our people. But I find myself among the Dutch, the French, the Germans, who have all come to the same social work here!"

"I developed the habit in the research lab I escaped from. They were testing the bad effects of smoking."

SCIENCE SHAPES LIFE

TV: SEE BETWEEN THE LINES

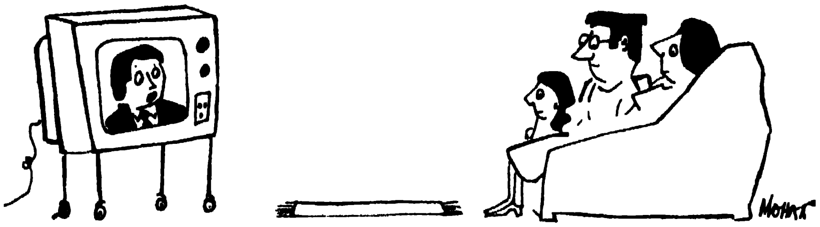
TELEVISION has more to it than meets the eye—health messages that may strike only your subconscious mind. According to a recent report in the *New England Journal of Medicine*, these could have adverse impacts on the viewer.

It has been estimated that American TV characters eat, drink or talk about food about nine times per hour. Most of the drinks that TV characters consume are alcoholic, with 36 per cent of the major characters drinking.

What's wrong with all that? you might ask. It's the absence of the consequences. For, the drinking and eating of the characters does not give them much trouble as one would experience in real life. It would appear that the unregulated eating and drinking gives them the healthy, sober and slim images they portray. Only four per cent of all US television characters are obese. Contrast that with the 25 to 45 per cent obesity of the general population.

Similarly, only seven per cent of all TV characters have medical problems. Yet, mysteriously, doctors and nurses come on the screen too often, their TV population being five times higher than in real life.

So, many Americans who have to wait several weeks for a medical appointment had better watch TV.



"Tarzan at 4.00 pm. And mind you, the brown drink Tarzan and Jane have at 4.07 pm is only chocolate milk..."

ANOTHER BUG FOR PATENT

"WE come up with toxic dumps like Love Canal or Seveso, and all we do is evacuate people. We come up with a useful chemical like DDT, find out it's toxic, and all we do is ban it." Now why did Ananda Chakrabarty (the scientist who was in the news last year after he tried to patent an oil-consuming bacterium) say that recently?

Chakrabarty and his colleagues have now come up with another bacterium that eats the herbicide 2, 4, 5-T. Chakrabarty collected bacteria from toxic environments and placed them with a little 2, 4, 5-T along with food. Over a period of nine months, he slowly increased the amount of herbicide and decreased the amount of food. Finally only those bacteria that could survive on the herbicide remained, the others having died. To make this possible, Chakrabarty and colleagues included a variety of plasmids in the solution. (Bacteria are known to absorb plasmids more easily than chromosomes.)

Chakrabarty

The herbicide 2, 4, 5-T which has contaminated a lot of fields and croplands may one day be removed if studies on the new bacterium are successful. Perhaps the technique could also be used to develop a strain of bugs that may eat up DDT as well. Chakrabarty is optimistic about that, and thinks all this will come about in just a matter of time.

FOR WOMEN ATHLETES ONLY

HERE'S evidence that athletic training delays menstruation. Researchers studied 38 Harvard University female runners and swimmers. It was seen that the start of training had an effect on the onset of menstruation. The pre-menarchal trained athletes (18 of the 38) began menstruation at an average age of 15, while the 20 post-menarchal trained athletes matured at an average age of 13, which is very close to the average for the general population, 12.7 years.

It was also noted (*Journal of the American Medical Association*, October 1981) that intense physical activity before menarche contributed to irregular menstrual cycles. Some 83 per cent of pre-menarchal trained athletes complained of this. Contrast this with the 40 per cent who had the problem among the other group.

Although the report says that a low fat ratio in the pre-menarchal trained athletes may be the chief factor responsible (conversion of androgens to estrogens takes place in the peripheral fat cells), it does not say what long-term effects the observed late menstruation can have on the reproductive and menstrual histories of the persons concerned.

PLACE YOUR ORDER WITH INFRARED

THE photo shows a portable computer terminal, about the size of a large pocket calculator which can well find use in restaurants with few waiters. The unit cuts down service time and the walking required by waiters. The terminal in the waiter's hand uses not wires but infrared light to pass on the customer's order to the kitchen or bar. Data collectors on the ceiling pick up the infrared light and pass it on to a computer. A small printer which is also linked to the infrared light system can be placed anywhere in the restaurant to supply the complete bill.

'Menu terminal'--*less tips too?*

THE QUARK SEEMS WITHIN REACH?

PHYSICISTS at Europe's Centre for Nuclear Research (CERN) feel they may not be very far away from trapping the elusive quark. Quarks are supposed to be the elementary building blocks with which all sub-atomic particles are made, and they are believed to have electrical charges that are fractions of the charge of the electron. (All other known particles have either no charge at all or have charges that are integral multiples of the electron's charge.)

It's the Italians at CERN under Prof. Antonio Zichichi who have been looking for the quarks. CERN's super proton synchrotron produces neutrinos, tiny uncharged particles with little or no mass. Zichichi's group uses an "avalanche chamber" which consists essentially of a suitable gas in a chamber with a very high electric field.

The neutrinos interact only very weakly with charged particles, and when they do, the detectors can show any electrically charged particle present, with the charged particle ionising the gas in the avalanche chamber. The Italian physicists appear to have found some three instances of such ionisation in 300,000 interactions, and believe they would need more accelerator time before they make sure these were caused by free quarks.

inside CERN

GROW TALLER

YOU must have heard of human growth hormone (HGH). This hormone is produced by the pituitary and is essential for growth. Medically, HGH is useful in treating certain types of dwarfism, besides in treating bone fractures, burns and bleeding ulcers.

So far the only source of HGH for these purposes was dead people, which made the hormone very expensive. Now, researchers have induced the bacterium *Escherichia coli* to produce HGH which they find has exactly the same effects as natural HGH.

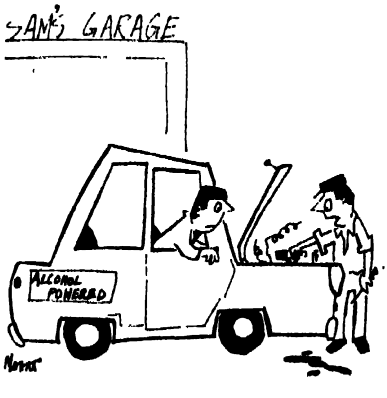
The researchers at the biotechnology company, Genetech, inserted the gene that codes for HGH in humans into the *E.coli* in 1979. This alone was considered a major breakthrough then. The next task was to observe how the bacterium responded to the new environment, and to determine what it produced — whether it was HGH or something else. It has now been found that structurally, too, the synthesised hormone is the same as natural HGH — and it works. Tests in rats with their pituitaries removed showed that these rats (whose growth gets retarded) put on weight fast. Tests with natural HGH, too, had similar effects on the rats.

GASOHOL ENGINES NEED NEW MATERIALS

WHILE alcohol is being used increasingly in place of petrol in automobiles in some oil-importing countries, the idea has met with quite a few problems that may be solved only with the use of new materials by the auto industry.

Brazil, with its surplus sugar, has led in the gasohol race, and hopes to have as many as two million alcohol-powered cars by 1985. But it has been seen with Brazilian alcohol fuel that a very high degree of purification is uneconomical. So Brazilian ethanol fuel contains at least 4 per cent water together with other impurities, especially acetic acid formed during the fermentation. As a result of this, fuel tanks in an alcohol powered car corrode, while rubber seals and pipes break or deteriorate.

Vehicle manufacturers are thus forced to look for new materials that can withstand these factors. Usually, cars have their fuel tanks made of sheet steel coated with a thin lead-tin alloy layer. This being insufficient, Ford of Brazil is now manufacturing fuel tanks using a more corrosion-resistant heavily tinned sheet, a material originally produced for equipment for the maple syrup industry in the US and Canada.



"Damaged insides, like all alcoholics!"

The chemical industry, too, is now working towards alcohol fuel-resistant materials. So it will not be wrong to envisage a plastic fuel tank. One US firm, for instance, has come up with a new type of fluoroelastomer to resist petrol-alcohol blends, synthetic lubricants, water-based hydraulic fluids and high-sulphur crude oils. The recent slump in the car industry has had an impact on the chemical industry. But it looks like new advances in the motor industry (like the switch to gasohol) will help the chemical industry recover from the blow.

[illegible]

[illegible] Shell and most other researchers say that giving up alcohol or drinking only moderate doses can reverse nearly all the effects in most cases.

THE "DUMB BLONDE" SYNDROME

THERE are people who simply cannot respond to psychotherapy. Try anything, but they won't budge although the persons may be attractive, charming and well-dressed. The symptoms may suggest a diagnosis of any psychological disorder from depression to schizophrenia, but they won't respond to therapy, including drugs.

Now an Australian psychiatrist, Norman Gold, and his psychologist colleague Julie Shaw have an explanation. They call it the "dumb blonde syndrome", and found the problem in 16 women who were considered "therapeutic failures" at a suburban psychiatric clinic. Gold and Shaw discovered low IQ levels in these women ranging from 69 to 88. After the tests Gold and Shaw explain that "the patients' below-average intellectual functioning was an unrecognised primary factor in misdiagnosis and inappropriate treatment". (The patients were never subjected earlier to IQ tests.)

"I hate to say this Mr. Peters, but psychotherapeutically speaking, you're a dumb blonde"

It may appear that a certain amount of intelligence is necessary for anybody to respond to psychiatric treatment, but are IQ tests themselves so perfectly unquestionable? And could it be possible for people with emotional problems to take IQ tests and respond to the questions asked like normal persons? Finally, the therapists, although apologetic about the male-chauvinistic tone of "dumb blonde syndrome", do not say why they examined only women!

HOT TIMES AHEAD

IT'S time the world viewed the impending global "greenhouse effect" more seriously. The increasing carbon dioxide levels on our planet may in the not too distant future offset global climatic, economic, environmental and social changes. These changes may affect the poorer tropical countries most.

Carbon dioxide increases in the atmosphere as a result of burning fossil fuels. According to a recent report, the temperature rise generally associated with a doubling of carbon dioxide concentrations -- about 3°C — would take the world's climate outside the range that has generally prevailed for the last several thousand years. And the day may not be very far off, for the concentration of carbon dioxide in the atmosphere has been growing ever since the start of the industrial revolution.

To understand the gravity of the problem, take the example of our neighbouring planet Venus, which is only 30 per cent closer to the Sun than the Earth is. So, you might expect an average temperature of just around 100°F on the Venusian surface—the temperature of Madras in a mild summer. But in reality the Venusian temperature is a killing 900°F. Until recently, the greenhouse effect on Venus had largely been a hypothesis, but data gathered from the Pioneer-Venus spacecraft has proved that the scorching heat of the planet is due to the carbon dioxide, which makes up 96 per cent of the Venusian atmosphere.

FROM WARTS TO CANCER

THE refined form of a chemical that has been used for over 40 years to get rid of warts will soon be used in the treatment of small cell lung cancer and resistant testicular cancer. The drug, named Vepesid by the pharmaceutical industry, is a semi-synthetic derivative of podophyllotoxin — which is a natural extract of the American mandrake root.

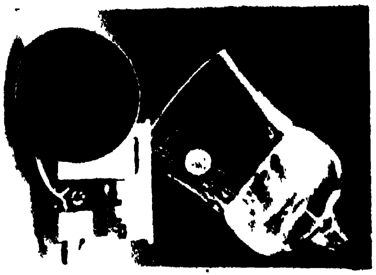
Tests with Vepesid have shown that it is the most active compound so far tested against small cell lung cancer. When combined with other cancer drugs, Vepesid is said to have shown a response rate of up to 96 per cent in 44 cancer patients with the lung cancer.

The new drug has an action that is unique among cancer-treating drugs. Cancer cells are known to go through stages of maturation and growth, and unlike other cancer-drugs, Vepesid arrests growth at the second stage of cell division.

Tests are on for the possible use of the drug to treat other types of cancers.

BIPOLAR TRIPLE CHIME

THE buzzing of door bells, the high-pitched bleeping of radio alarms or the jingling of kitchen timers can hardly be described as melodious. An electronics firm has now come with an integrated circuit (IC) that can be used to work a triple chime with harmonically tuned frequencies musical to the ear. With minimum circuitry, comprising a resistor, two capacitors and an electrolytic capacitor, a gong circuit can be accommodated, together with a small 8-ohm loudspeaker, in almost all types of devices. The low current draw of typically 1 mA means long-period battery operation



PITY THE POOR MR. RAMANUJAN

THE May 1981 issue of the US magazine *Psychology Today* has an article on the making of prodigies and how they fare in later life by Howard Gardner who is co-ordinator of Harvard Project Zero, a research group that investigates artistic development. Gardner is also the author of several books, his latest being *Artful Scribbles*. What may interest Indians is a paragraph in his *Psychology Today* article, quoted below.

"Likewise, even the most gifted mathematician cannot make genuine innovations living in a culture in which mathematics has been little developed. That, indeed, was what befell Ramanujan, [illegible] who was [illegible] in India, [illegible] ments of several centuries of mathematicians. However, the same work had already been performed in the West, and so when he finally arrived in England in the 1930s, it was too late for him to be at the forefront of the profession."

Any comments?

Ramanujan—*West, forefront East, backyard?*

Thermoluminescence

—*a versatile new tool*

K.S. V. Nambi

Thermoluminescence techniques are finding applications in an increasing number of fields

AFTER the Hiroshima-Nagasaki bombing in 1945, a Joint US-Japan Atomic Bomb Casualty Commission was instituted to study the ill-effects of the atomic bomb, and its first major task was to get to know the amount of radiation (dose) received by individuals. But so many were the uncertainties and unknowns involved that the dose estimates varied widely; a measured value was badly needed to work out a proper basis for the dose calculations. A Japanese professor had the ingenuity to measure the thermoluminescent light emitted by roof-tile samples collected from various parts of the ruined cities. Based on these, he could tell the radiation levels that had prevailed after the bombing.

More recently, the only available radiation dose data in the Three Mile Island Nuclear Power Station accident in the USA came from just five thermoluminescence dosimeters which happened to be lying exposed to the environment around the reactor. The data could help estimate radiation-induced cancer risks to the population in the region.

Indeed today the uses of thermoluminescence are numerous. Besides the measurement of radiation exposure in nuclear plants and in medical fields, it is used in archaeology for determining the age of ancient objects, and for checking whether an archaeological object is genuine or fake; in geology, it is used for dating and deciding the origin of geological formations and, possibly, even for ore prospecting and earthquake predictions. It can also be used in forensic science and in a wide range of quality control and analysis.

Historically, thermoluminescence must have been observed even during the Stone Age (civilisation more than 10,000 years old and which used stone implements, some of them quite often made of limestones) as certain limestones, when heated, give off a glowing light. The most acclaimed first recorded observation of thermoluminescence in English literature is, however, credited to Sir Robert Boyle. In an evening lecture to a gathering of the Royal Society of London, on 28 October, 1663, he said: "I also brought it (Lord Clayton's diamond) to some kind of glimmering light by taking it into bed with me and holding it a good while upon a warm part of my naked body". However, the name "thermoluminescence" was perhaps first used by E. Wiedemann of Germany in 1903 while explaining his observations on the luminescence of fluorites (calcium fluoride mineral).

What is thermoluminescence, anyway? It is the phenomenon of light emission upon heating a material which has been previously excited. (Excitation is a process by which energy is imparted to a material; energy absorption leads to excitation of electrons in the material and hence the name.) All types of radiations such as gamma rays, X-rays, alpha rays, beta rays and light rays can "excite" a material, but to widely different extents. There are also mechanical means of exciting a material such as applying pressure and causing friction. But radiation-induced thermoluminescence is the most important because it holds promises of a wide range of applications. Out of the excitation energy imparted, a very large portion is almost instantaneously dissipated by various processes such as heat and light and only the balance is absorbed and stored in the material. On subsequent heating, this energy is released and some of it may be in the form of light, which we call thermoluminescence; even the most sensitive thermoluminescent materials known today have thermoluminescence conversion efficiencies of the order of a few per cent only. In recent times, the phenomenon has been correctly termed as thermally stimulated luminescence (TSL). Exactly how thermoluminescence occurs could be explained in terms of the band theory of solids (see box on p. 14).

Several materials exhibit thermoluminescence. Among natural materials, selected rocks, minerals, soils, ice and certain plants show thermoluminescence after proper excitation; among man-made materials are potteries, ceramics, glasses, a good number of semiconductors and insulators, including polyethylene and PVC. The presence of trace amounts of chemical impurities, for example, the presence of rare earth elements like dysporium (Dy), terbium (Tb) or samarium (Sm) in fluorites greatly affects thermoluminescence, sometimes increasing it, sometimes decreasing it. The crystal structure of the material (cubic, hexagonal or tetragonal, etc) as well as its thermal history (for example, in natural minerals, whether they were formed by a sedimentary process at ambient temperatures or formed by a volcanic lava flow) determine to a very great extent the thermoluminescence capability of a material. Most of the laboratory investigations towards understanding the underlying physical phenomenon have been carried out on various inorganic compounds (crystals or microcrystalline powders) after X or gamma irradiation. In general, radiation-induced thermoluminescence is more apt to occur in hard, colourless, inorganic crystalline compounds with a simple lattice structure containing small-size cations and anions — for example, lithium fluoride, calcium fluoride, calcium sulphate, etc. A rough classification for the cation-anion combination in decreasing order of thermoluminescene intensity after gamma irradiation may be as follows:

Anions	**Cations**
(a) High thermoluminescence intensity	
F$^-$, Cl$^-$, CO$_3^=$, SiO$_3^=$, O$^=$, SO$_4^=$	Li$^+$, Na$^+$, K$^+$, Mg^{++}, Ca^{++}, Sr^{++}, Al^{++}
(b) Medium thermoluminescence intensity	
HPO$_4^=$, Br$^-$, I$^-$, PO$_4^{\equiv}$	Pb^{++}, Cd^{++}, Ba^{++}
(b) Low thermoluminescence intensity	
CrO$_4^=$, Cr$_2$O$_7^=$, S$_2$ O$_H^=$	Fe^{+++}, Fe^{++}, Mn^{+++}, Mn^{++}, Co^{++}
Fe (CN$_6$)$^{\equiv}$, HSO$_4^-$, MnO$_3^-$, NO$_3^-$	Ni^{++}, Cu^{+}, Cu^{++}, Ag$^+$, Ag^{++}, NH$_4^+$

Thermoluminescence dosimetry (TLD) offers a very inexpensive and sensitive method of measuring atomic radiations. After an exposure, the TLD can be heated and the thermoluminescence emitted can be measured and related to the radiation dose it received. The same TLD can be reused (until recently, photographic films were used for measurement of radiation doses received by working personnel and, obviously, new films had to be used for each measurement). Even very low levels of radiations, like the natural radiation background, can be measured by exposing the TLD for long periods, say, a week or a month or even a year, and evaluating the total dose received over the particular period. In case of unexpected radiation exposures, like in a nuclear reactor accident or an atomic explosion, the instantaneous, high level of radiation is absorbed by TLDs and the radiation dose could be evaluated later whenever TLDs are retrieved. In the absence of any TLD, materials like roof-tiles and wall-bricks could be used to evaluate the radiation dose. Though these materials yield very low thermoluminescence, it is enough to detect very high radiation doses involved in nuclear accidents.

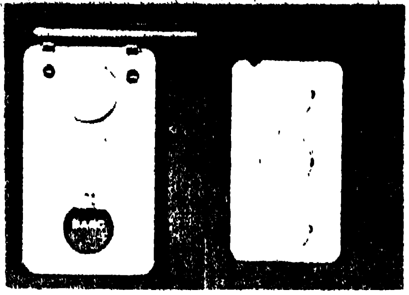


Fig. 1 Thermoluminescence dosimetry (TLD) badge worn by radiation workers in nuclear power stations and in the Bhabha Atomic Research Centre

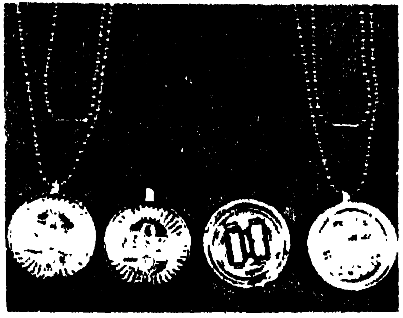


Fig. 2 TLDs used for measuring natural radiation background. Radiation is detected by CaF_2 powder filled in a pair of brass capsules kept inside the lockets. These can also be conveniently worn by people in neck chains for studies like population dose distribution along the monazite beaches of Kerala

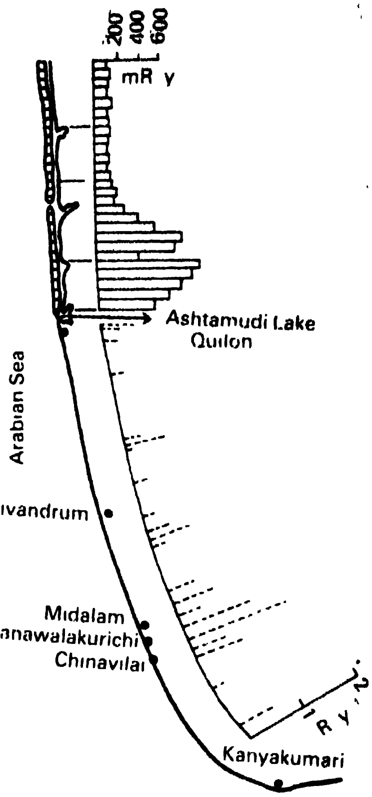


Fig. 3 Radiation levels along south-western coast of India—a schematic representation. A detailed study using TLDs has been completed only in the northern region of this coastal stretch (shown by histogram)

In India, TLD badges (Fig. 1) are worn by radiation workers in all the nuclear installations. The badge employs three teflon discs containing $CaSO_4$: Dy as the thermoluminescence phosphor, and it can give information on X-ray (in the case of radiologists) as well as beta and gamma (in the case of reactor workers) radiation exposures. Special TLDs (Fig. 2) have been used by the Health Physics Division of the Bhabha Atomic Research Centre in their studies of radiation exposures to the population living in monazite (contains radioactive thorium, an important fuel source in atomic energy; thorium gives out alpha, beta and gamma radiations and this results in above-normal radiation levels along the monazite beaches) beaches of the Kerala sea coast, and natural radiation background elsewhere throughout the country (at about 80 principal meteorological stations). Fig. 3 shows typical distribution of radiation levels along the Kerala coast.

TLDs are also widely used for radiation dose estimation in medical fields like in diagnostic radiology, radiation therapy and nuclear medicine. Some of the striking applications are in interstitial intracavitary radiation therapy and in the therapy of thyrotoxicosis. For example, in the case of radiation treatment of cervical cancer, the dose to the rectum is accurately determined by inserting a flexible plastic tube containing a set of equally spaced vials/pellets of TLD and withdrawing it after a known interval of time. In the case of thyrotoxicosis therapy, it is necessary to know the effective half-life of radioiodine in the patient's thyroid to evaluate before hand the thyroid dose to be delivered. After administering the test quantity of radioiodine, the patient is made to wear a convenient neck band with a set of TLDs which is replaced every day at a specified time; the patient can report to the hospital with all the used TLDs after about a week and evaluation of the doses from these TLD sets of sequential dates provides the decay pattern. Before the advent of TLDs, each patient had to report to the hospital everyday for a week.

To archaeologists, thermoluminescence has been a boon for the following four reasons: (i) thermoluminescence dating is absolute and

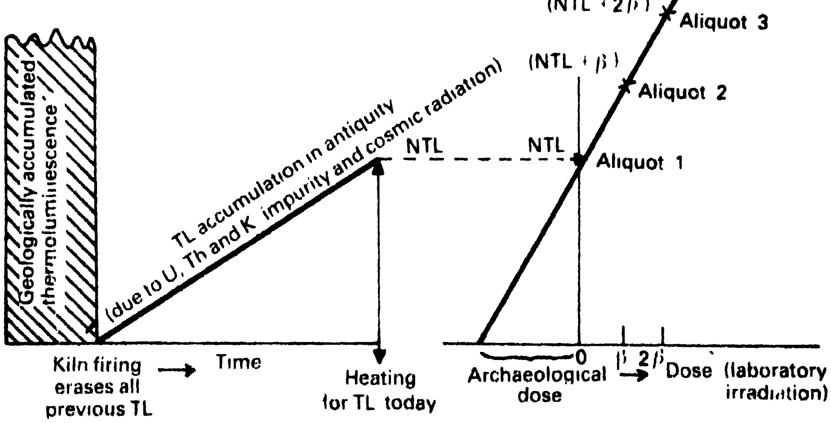

The rmoluminescence
Geologically accumulated thermoluminescence
TL accumulation in antiquity (due to U, Th and K impurity and cosmic radiation)
NTL
NTL
(NTL + β)
(NTL + 2β)
Aliquot 1
Aliquot 2
Aliquot 3
Kiln firing erases all previous TL
→ Time
Heating for TL today
Archaeological dose
0
β
2β
→ Dose (laboratory irradiation)

Fig. 4 Schematic representation of the TL dating principle. TL=thermoluminescence; NTL=natural thermoluminescence

How does thermoluminescence occur?

PHYSICISTS explain the thermoluminescence process with the help of "the band picture of the solids" (Fig. 4). The normal energy state (ground state) of the electrons in a material (before excitation/irradiation) is represented by the valence band. The next higher allowable energy states of all the electrons overlap and constitute the conduction band. The energy gap between these two states is called the forbidden band. Theory demands that no electrons can exist in the material with energy states falling in the forbidden gap. When the material is "excited", say, by an incident gamma ray, some electrons (originally in the valence band) are excited and they attain energy states corresponding to the conduction band. Normally, these electrons cannot remain excited indefinitely, that is, the life-time of an electron in the conduction band is very short and the electron attains its ground state immediately, giving away the energy to warm up the crystal lattice or in the form of light (fluorescence).

However, an impurity atom (with an appropriate ionic size and charge) present in the material can have an energy state in the forbidden band, for example, magnesium in lithium fluoride; these are called metastable energy states having appreciable life-times. An excited electron can find itself in this state rather than getting back to its normal valence band state. Now we say an electron is "trapped". In analogy, it is also visualised that a "hole" (absence of an electron) is trapped at an energy state very close to the valence band. Depending upon the energy level of the [illegible] respect to the valence band)—called the trap depth—the electrons will remain trapped for a definite period; the greater the trap depth, the greater will be the life-time of the electrons in the trapped state for a given temperature.

This stage corresponds to energy storage after the initial excitation of a material. If now the material is warmed, the heat energy supplied is able to stimulate the electrons out of the trap (detrapping) and the electrons return to the ground state; if conditions are favourable (for example, if the particular atom has a light-emitting property) for the emission of light in this "return process", then we have thermoluminescence.

If the Band Theory of Solids sounds abstract, it is possible to understand the thermoluminescence mechanism in terms of real physico-chemical processes taking place in the material. Consider, for example, the case of thermoluminescence of fluorites containing dysprosium impurity (commercially, a very sensitive TLD material called CaF_2:Dy phosphor is available). From spectroscopic analysis, it is known that Dy^{3+} is present in the Ca^{2+}-F cubic lattice. On X or gamma irradiation, an electron from the fluorine is easily ionised (knocked out) and this is captured by Dy^{3+}, resulting in the formation of Dy^{3+} Both F^0 and Dy^{2+} are highly stable states and the charges remain trapped for very long periods. On warming the crystal, the thermally less stable "hole" diffuses out and finally reaches Dy^{2+} recombining with its original partner—the electron. This recombination energy excites the Dy^{3+} ion which returns to the ground state emitting its own characteristic yellowish white light (thermoluminescence).

[illegible] gives rise to a green thermoluminescence while Sm^{3+} impurity gives rise to a red thermoluminescence.

There is another aspect to consider here—the electrical neutrality of this process of incorporating an impurity atom in the crystal lattice and how this, in turn, is reflected on the thermoluminescence. The excess positive charge of the impurity ion gets neutralised in the crystal in a variety of ways depending upon the conditions of crystal growth: for every two ions of Dy^{3+}, three extra Ca^{2+} ions can enter in interstitial positions; Dy^{3+} ions can replace a Ca^{2+} ion and an extra F^- ion can enter an interstitial position; for every Dy^{3+} ion entering the crystal, an O^{2-} ion from air can enter the crystal, replacing one F^-ion and so on.

These constitute various types of the so-called lattice defects. What it means, in terms of energy states, is that different types of traps will be possible with different trap depths. And that when the crystal is being warmed, after irradiation, thermoluminescence will accordingly be emitted not at just one temperature corresponding to detrapping in one type of traps but at a succession of temperatures corresponding to a series of different types of traps. This is illustrated in Fig. 5 which is called the thermoluminescence glow curve. The glow curve generally exhibits many peaks, each corresponding to a trap with a different energy depth.

What make the thermoluminescence phenomenon an extremely versatile tool in a variety of applications are the following: (i) the thermoluminescence intensity (that is, the area under the glow curve) is directly proportional to the net radiation dose received by the material; this relation exists over a wide range—from a few mRad to about 100,000 rads beyond which saturation sets in and the thermoluminescence yield levels off for further radiation doses (Fig. 6). The saturation and slight decrease in the thermoluminescence yield at very high doses could happen due to the following reasons: no more traps are available for further irradiation in the high doses; no more light-emitting atoms are available while heating the sample; and possible radia-

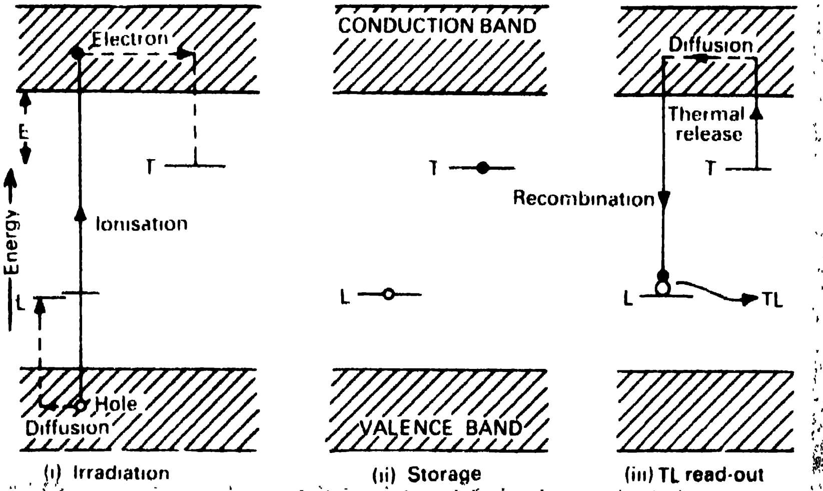


Fig. 4. Band model representation of the thermoluminescence (TL) process. (i) Ionisation by irradiation results in trapping of electrons at the metastable state T and holes at L. (ii) For sufficiently deep traps (E=2 eV and above), the life-time of the trapped charge carrier is ≥ 10^6 years! (iii) Laboratory heating causes detrapping of charge carriers and TL is emitted as a result of radiative recombination.

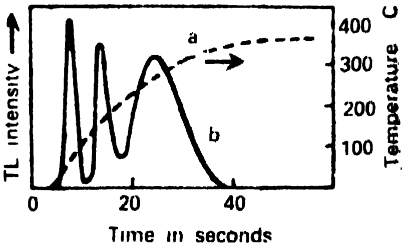


Fig. 5. TL glow curve shapes vary with various heating patterns. Above is the glow curve for CaF_2 [illegible] using a constant current [illegible]

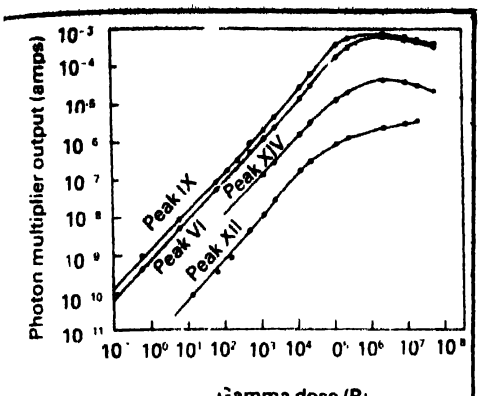


Fig. 6 Growth curves with gamma dose for different TL glow peaks of $CaSO_4(Dy)$

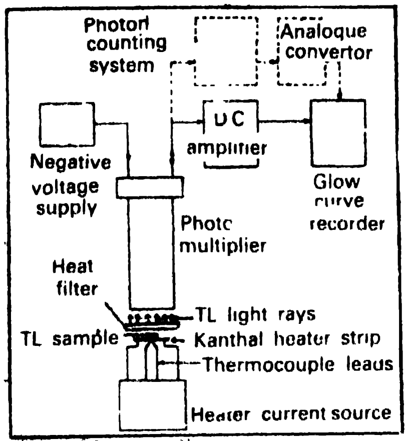


Fig. 7 Schematics of a TL reader. The dotted part shows the alternative system, photon-counting instead of the DC amplifier

tion damage to the crystal structure at high doses. (ii) There exist one or more traps with sufficient energy depths (and hence long life-times) so that energy is stored indefinitely in such traps after excitation (radiation exposure). Normally, in a majority of materials, thermoluminescence peaks occurring at temperatures around 300°C or above belong to this geologically stable category. (iii) The probability of detrapping an electron at a temperature T°K is given by $p = se^{-E/kT}$ where k is the Boltzman constant, E is the trap depth and s is a constant for the trap called the frequency factor. If all the parameters are known, the decay of a particular thermoluminescence trap can be predicted. (iv) Different types of radiations like alpha, beta and gamma have different capabilities to produce thermoluminescence in a given material. (v) The thermoluminescence intensity, for the same radiation dose, is proportional to the concentration of the light-emitting impurity ions in a given material. (vi) The thermoluminescence glow curve pattern, the thermoluminescence efficiency and the [illegible] of thermoluminescence of any [illegible] points to the time when a pottery was baked in the kiln. (So far, potteries have been dated on the basis of their style and fabrication technique; rarely could associated organic matter in a pot be sufficient in quantity to yield a carbon-14 date); (ii) thermoluminescence dating is possible even beyond 30,000 years which is approximately the upper limit for C-14 dating; (iii) authentication of an antique pottery is possible from simple and quick thermoluminescence measurements on even a few milligrams of a powder sample drilled out from a hidden corner portion of the antique piece; and (iv) thermoluminescence characterisation offers immense possibilities in identifying the source of ancient potteries and ceramics.

What is the principle of thermoluminescence dating (Fig. 4)? A pottery piece consists of grains of minerals such as quartz, feldspar, zircon, apatite, etc embedded in fine-grained clay, the whole thing having been fired at temperatures in the range of 500°C to 1000°C. All previously stored thermoluminescence in the pottery piece is erased during this kiln-firing. Subsequently, alpha, beta and gamma radiations from radioactive impurity elements like uranium, thorium and potassium which are invariably present in the clay and the cosmic radiations start building up the thermoluminescence; when the pottery gets buried, one more source, radiations from the burial soil, also adds to this continuous build-up. (The shallow traps will continuously fade as even they are being continuously irradiated, but the deeper traps with the potential to give rise to high temperature peaks around 300°C or more continue to build up without any fading.) From an analysis of the pottery and soil samples, one can know the uranium, thorium and potassium contents and hence (from a knowledge of their half-lifes and the types of radiations emitted by their radioisotopes) estimate the rate at which the pottery piece was being irradiated throughout antiquity (rad/yr). From a measurement of the thermoluminescence emitted by the sample at present times (natural thermoluminescence, NTL) and by a proper laboratory calibration giving known artificial radiation doses, one can estimate the archaeologically accumulated radiation dose (rads) in the pottery. The age is given by the simple equation,

$$\text{Age (before present)} = \frac{\text{Dose acquired since kiln-firing}}{\text{Annual dose}}$$

Prof. M. J. Aitken and his group at Oxford University, England, have done pioneering work in the application of thermoluminescence techniques in archaeology—the development and standardisation of dating techniques, methods to detect forgeries, etc. In India, the BARC and the Physical Research Laboratory, Ahmedabad, have been working in this field. Table 1 gives results of three selected studies. In all these, thermoluminescence dates have been invaluable.

In the first case, Kankar (calcium carbonate) nodules from buried soil excavated from an important archaeological site in the Lower Narmada Valley near Dhegam in Gujarat have been dated. Prominent buried soil profiles are seen in sections of the Lower Narmada Valley and Lower Paleolithic tools have been occasionally found here. As the strata do not yield fossil bones or pollens, it was necessary to find a period framework for the buried soil, a product of weathered silt. Although C-14 data existed, these were based on some presumptions about the formation of Kankar, and independent confirmation of the date was needed. The C-14 dates and the thermoluminescence dates agree well and are shown in the table. In the cases of burnt clay samples from a pre-historic cave in Andhra Pradesh

Table 1. TL and C-14 dating of archaeological objects

TL laboratory	Sample description	Age in years	
		C-14 estimate	TL estimate
Bhabha Atomic Research Centre, Bombay	Kankar nodules in a buried soil profile in the Narmada river bank near Dhegam, Gujarat	22452 ± 550 (C-14)	22890 ± 8%
—do—	Burnt clay from a pre-historic cave at Muchchatta Chintamani Gavi in Andhra Pradesh	Upper paleolithic (>10,000)	17390 ± 10%
Physical Research Laboratory, Ahmedabad	Ochre colour pottery from Sringaverpura (associated with the Ramayana period)	Pre-3000	2900 ± 380

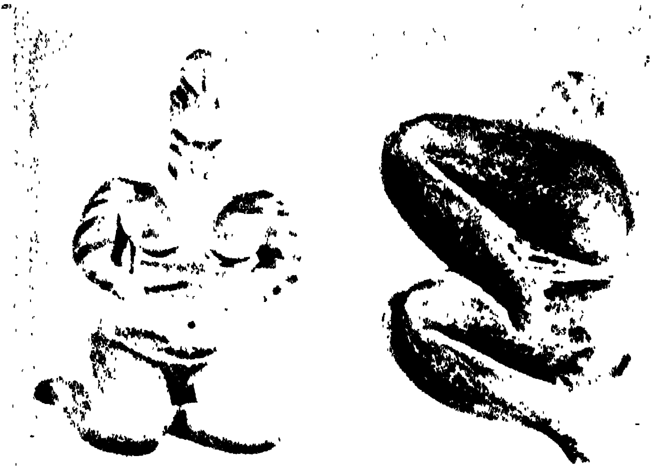


Fig. 9 A figure (front and bottom) claimed to belong to the Hacilar Style, Turkey. TL studies (note the drill hole in the buttock for sampling) proved it to be a recently fired specimen. (*Archaeometry* 13, 2 (1971), 89-141, plate 14)

and pottery from a *Ramayana* site in Uttar Pradesh, accurate age estimates were not available at all.

The greatest impact of thermoluminescence dating has perhaps been on the authentication of art objects, that is, differentiation between fake and genuine objects. Just an estimation of the archaeological dose will tell whether an object is genuine or not. Thermoluminescence studies have already proved that 48 of the 66 vessels and figurines claimed to have been from Hacilar in Tukey, and belonging to the prehistoric period, were modern fakes (Fig. 9). Excavations near Hacilar in the late 1950s had revealed the site of a pre-historic settlement belonging to the sixth millennium BC with a distinctive style of grey and painted pottery and figurines. But doubts had been raised about the authenticity of some of the vessels claimed to be from Hacilar which had passed into public and private collections in Europe and America. There were fissures on the surface of the painted decoration not previously noted on pre-historic pottery and there was an apparent contrast in the fabric between these and the original vessels. What complicated the matter further was that genuine objects from clandestine excavations around Hacilar were also coming into the antiquities market. Sixty-six objects in the Hacilar style from various collections were, therefore, thermoluminescence-dated by the Oxford group, and 48 turned out to be forgeries. Conversely, in the famous 'Glozel controversy, a wide range of baked clay tablets and jars unearthed by a farmer at Glozel in France in the 1920s were branded a hoax by archaeologists, but have now been found, by thermoluminescence dating, to be a little over 2000 years old. The controversy, however, lingers. Archaeologists do not seem to have come to full grips with thermoluminescence techniques, and so these are not yet popular with them.

Applications in geology

Though dating is the main application in geology also, there is a serious limitation—thermoluminescence saturation encountered in a majority of the situations. As we have seen in radiation dosimetry, most of the materials exhibit thermoluminescence saturation around a dose of 10^5 rads (Fig. 7). And, unlike in archaeology, such a dose will be easily reached in geology as one is dealing with self-irradiations extending up to billions of years. Hence thermoluminescence dating holds out better promise only in Quaternary Geology, say up to a million years.

The dating principle is the same as in archaeology but the starting point of the TL clock here will have to be clearly ascertained (akin to the kiln-firing of potteries). Events which can be dated in geological applications are the time of crystallisation, time of sedimentation, time of volcanic eruption, time of any geothermal event, etc. In India, the age of monazite deposits along the Kerala and Tamil Nadu sea coasts as well as the age of radioactive minerals in Singhbhum district, Bihar, have been successfully dated to be respectively 44 + 12 million years, 118 + 120 million years and 940 + 160 million years, respectively.

But thermoluminescence-dating of geological samples has consistently shown a peculiar pattern; the thermoluminescence-estimated age comes out very much lower than the known age of the samples, even when there is no saturation. Why is this so? It has been now realised that even a few parts per million level of alpha-emitting impurities like uranium and thorium continuously create new traps (see box on p. 14) by alpha irradiation over millions of years, and this means that the thermoluminescence storage capability of the material has been continuously changing with time; in the absence of a standard radiation calibration, any evaluation generally leads to underestimation of the actual age.

Even with this uncertainty, thermoluminescence dating in geology can be significant where relative dating of a given series of samples from the same location, say, samples drilled from the deep sea, is concerned. For, the relative dating will still hold good, and the rate of formation of a sea coast or the rate of sedimentation in sea beds can be worked out. Two typical Indian examples can be cited. Thermoluminescence dating results from the Arabian sea core samples off the Tarapur sea coast in Maharashtra showed that the depthwise pattern pointed to a probable geological fault at the period corresponding to about 1600 metres depth (Fig.12). Tectonic activities had been predicted earlier by geologists based on other conventional considerations and the thermoluminescence results now provide a direct evidence. The sand deposition rate at Pondicherry beaches has also been estimated, using thermoluminescence techniques, to be about 5 cm per thousand years.

Besides dating, either absolute or

Fig. 10 Some archaeological objects from Glozel, France

Antiquity XLVIII, 1974, plate xxx

relative, thermoluminescence can also be used to determine the genesis of the geological formation of a mineral. It is possible, for instance, to identify calcite crystals of hydrothermal, metamorphic and sedimentary origins from the thermoluminescence glow curve pattern, that is, either the appearance of entirely new peaks or differences in the relative heights of pairs of 'indicator' peaks. Similarly, the diagenetic (process of lithification after sedimentation) status of limestones, the degree of dolomitisation (process of replacing calcium by magnesium in calcium carbonate) of calcites, relative amounts of manganese and magnesium in dolomites can all be inferred from a thermoluminescence glow curve pattern comparison.

Two important areas of geological applications where the potentialities of thermoluminescence techniques await to be fully exploited are ore prospecting and earthquake prediction. A rock is an assemblage of minerals and thermoluminescence from a rock is due to one or two of the minerals in it which are thermoluminescence-sensitive. The growth of an ore deposite will affect the mineral constituents of the rocks around it consistently. The thermoluminescence of the rock samples will, therefore, either steadily increase or decrease towards an ore deposit, depending on whether the thermoluminescence-sensitive materials have been "enriched" or "depleted" in the original mineral assembly in the rock. The location of an ore body can be identified from analysing the pattern of thermoluminescence intensity/sensitivity or any thermoluminescence anomaly in a region. In the case of radioactive mineral deposits, the judicial use of very sensitive environmental TLDs may lead to the location of the ores. With thermoluminescence phosphors like CaF_2:Dy or $CaSO_4$:Tm which have enhanced response to alpha radiations, it may be possible to detect distant uranium ore bodies by registering the alpha exposures from the diffusing radon gas. Thermoluminescence will be cheaper than chemical analysis methods for minerals.

In areas chronically subjected to earth tremors, rock bursts, faulting, etc, pressure builds up considerably in the earth before they occur. If a convenient thermoluminescence-sensitive mineral occurs abundantly in such a region, core samples can be removed periodically to examine their thermoluminescence. Pressure-induced changes in thermoluminescence patterns can be easily identified and an impending 'tectonic disturbance' can be foretold. Alternatively, pairs of environmental TLDs, one pre-exposed and another clean, can be planted at various exploratory bore holes in a region and retrieved periodically to examine the thermoluminescence patterns: a systematic depletion of thermoluminescence in the pre-exposed TLD from its initial level or a build-up at a rate over and above that due to environmental radiation will indicate a 'pressure build-up' and hence an impending disturbance. These techniques have not been used in practice yet. Applications of thermoluminescence techniques may help in regions in Assam which are prone to earthquakes and in mining regions in the Kolar Gold Fields where rock bursts have been reported.

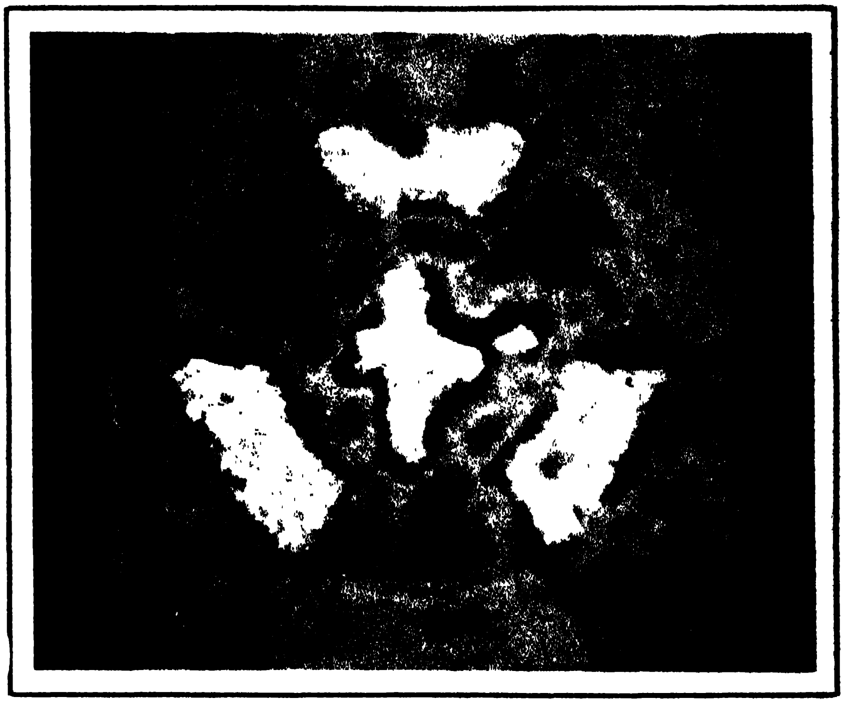


Fig. 11 The plate represents an autoluminograph of a design, the emblem of the Indian Association for Radiation Protection, made of irradiated TL phosphors and subsequently heated. White (Ca SO_4 : Dy), violet (Ca SO_4:Tm), green (CaF_2·Mn) and red ($CaCO_3$:Mn) The changes in TL emission colours induced by different activators in the same host lattice and the same activator in different host lattices are amply demonstrated.

Forensic science

A major task in forensic science laboratories is to identify an evidentiary material with a similar material of known origin. Some of the commonly encountered contact traces in criminal cases are glass pieces, soils, etc. But, quite often, the material available as evidence is very small in quantity. Evidently, thermoluminescence can offer an effective tool in such comparisons and "source-identifications". Though very few attempts have been made so far in analysing evidentiary materials this way, available results indicate that thermoluminescence can be used as an exclusory evidence, when thermoluminescence patterns do not match, it can be said with reasonable confidence that a particular source is not connected with the evidentiary material. Thermoluminescence analysis of autolamp glass covers is likely to get popular in solving 'hit-and-run' traffic accident cases.

Thermoluminescence techniques have not yet found popularity in quality control or chemical analysis although possibilities exist in selected cases. For example, the feldspar content in ceramic products can be identified by measuring their thermoluminescence after artificial irradiation (thermoluminescence will be directly proportional to the feldspar content at trace levels). Certain surface catalysts like aluminium oxide can be quickly and efficiently evaluated by their thermoluminescence sensitivities as lattice defects which cause adsorption reactions. In such cases, it will be necessary to monitor the glow curve pattern rather than only the net thermoluminescence output. Recently, it has even been shown in the case of

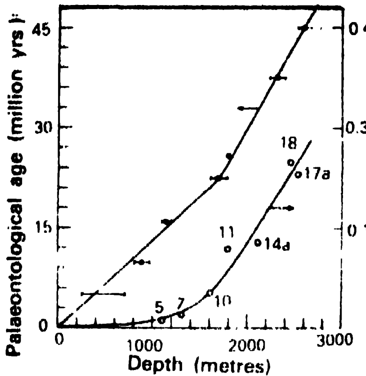


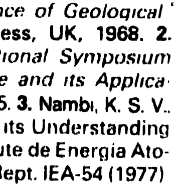
Fig. 12 The depthwise TL age profile as well as palaeontological age do not show a uniform increase, a break, indicated around 1600 metres depth, is being associated with a tectonic disturbance

textile fibres that the low temperature thermoluminescence glow curve (the fibre is cooled to, say, 77°K, irradiated, and then warmed to room temperature simultaneously recording the thermoluminescence output) changes can be correlated with structure differences and/or chemical tracer impurities.

Meanwhile, X-ray excited optical luminescence (XEOL) is fast becoming a sensitive analytical tool in pure chemical analysis to detect elements like lanthanides (La, Ce, Pr, Nd, etc), silver and manganese at parts per billion level (10^{-9} gm/gm) in certain matrices. This XEOL will have a close correlation with thermoluminescence in quite a few cases (XEOL is thermoluminescence at room temperature) and if the glow curve patterns are well established, XEOL analysis can be made at a judiciously chosen elevated temperature which will improve the luminescence output. This will help detect still lower levels of material contents.

The future

Thermoluminescence studies in recent times have become increasingly popular (Raman Effect in earlier years is perhaps the only parallel). And the trend is likely to continue in the near future. To cite some latest developments, one can take the biological and biochemical systems. Thermoluminescence results could indicate the poorer stability of benzoic acid when in the ortho form, the radiation damage in nucleic acids and proteins, the interaction between salt and proteins, and so on. Thermoluminescence patterns of bones and teeth have also been recorded recently and this holds out promise in forensic science applications and dating. As for basic research, future work should be directed to get more insight into the trapping parameters. If the thermoluminescence process is considered to consist of three stages, of energy absorption, storage and stimulated emission, it is the trapping parameters (which dictate storage) that have remained impregnable to analysis. The ultimate aim will be to be able to predict the thermoluminescence characteristics of a material from a knowledge of some of its critical physico-chemical properties.



Dr Nambi leads the Thermoluminescence Dosimetry Group of the Health Physics Division of the Bhabha Atomic Research Centre, Bombay After obtaining his PhD in physics from Gujarat University, he was a Research Scholar at the Research Reactor Institute, Kyoto University, Japan.

Recommends reading **1.** Mc Dougall D J (ed). *Thermoluminescence of Geological Materials,* Academic Press, UK, 1968. **2.** *Proceedings of the National Symposium on Thermoluminescence and its Applications*, BARC, Bombay, 1975. **3.** Nambi, K. S. V., "Thermoluminescence—its Understanding and Applications", Institute de Energia Atomica, Sao Paulo, Brazil, Rept. IEA-54 (1977) **4.** "Thermoluminescence Dosimetry and Applications", special issue of the *Bulletin of Radiation Protection,* The Indian Association for Radiation Protection, BARC, **2,** 4, 1979. **5.** Mc Kinlay, *Thermoluminescence Dosimetry,* Adam Hilger, UK, 1981. **6.** Oberhofer and Scharmann, *Applied Thermoluminescence Dosimetry,* Adam Hilger, UK, 1981.

Dating deserts

THE antiquity of deserts, occupying nearly a fifth of the global land area, has remained a polemical issue. For example, the estimates for the origin of the Thar desert in India range from several thousands to a few hundred years. The implications of such an assessment are enormous. If it can be conclusively established that the deserts are of a recent origin, it would necessitate immediate and effective remedial measures to reverse the trend of increasing desertification. On the other hand, if they are found to be of a distant origin, eco-planning will have to be done on a long-term basis. Such studies on the global problem of advancing deserts have been severely handicapped in the absence of any reliable temporal framework.

Deserts have nothing to offer except the sand that constitute them and thus no conventional radiometric technique can be applied. It now seems possible that one can date the depositional event of these sediments with thermoluminescence. At the PRL, we have recently developed this application with encouraging results. With this dating tool, scientists studying palaeoclimate, dune-dynamics and land-use planning will receive a powerful support.

However, a question arises. How can one date a sand sample without any firing (analogus to kiln-firing in the case of archaeological objects)? How does the geological thermoluminescence in the sands get erased? Although there is no analogus firing event in the case of sand dunes, the Sun does the trick. The exposure of sand grains to sun during their weathering and transport results in the bleaching of their geological thermoluminescence. This bleaching, though not complete, is effective enough to reduce the thermoluminescence level to a small residual value. These sand grains, once embedded in a dune, get shielded from further exposure to sun, and thereafter start acquiring thermoluminescence due to radiation exposure from their new environment, over and above the predepositional thermoluminescence level. Thus the thermoluminescence that is measured in the laboratory (I_{nat}) comprises both: (i) the predepositional thermoluminescence (I_0); and (ii) thermoluminescence acquired by the sample since its shielding from sun (I_d), that is, $I_{nat} = I_0 + I_d$.

Thus sediment thermoluminescence (I_d), when scaled by the appropriate annual rate of thermoluminescence acquisition, provides the date of the depositional event. Careful laboratory simulation of sunbleaching and calibration experiments enable an estimate of predepositional thermoluminescence level and this when substracted from the observed thermoluminescence gives the thermoluminescence acquired in the sediment. The annual rate of thermoluminescence acquisition, that is, the annual radiation rate, is worked out by a laboratory estimation of the natural radioactivity due to uranium, thorium and potassium, using standard techniques.

This technique has been applied to three sites in the Rajasthan desert, Amarpura (Didwana), Bagor (Bhilwara) and Langhnaj (Gujarat), and the dates obtained showed an increase in thermoluminescence with the depth of the dune. They also suggest a very gradual accretion of the dune sand. Thermoluminescence age estimates agree with radiocarbon and archaeological dates of the samples. The method can be applied to any windblown deposits that can satisfy the criterion of sunbleaching.

Thermoluminescence techniques have also been used to study meteorites and lunar samples.

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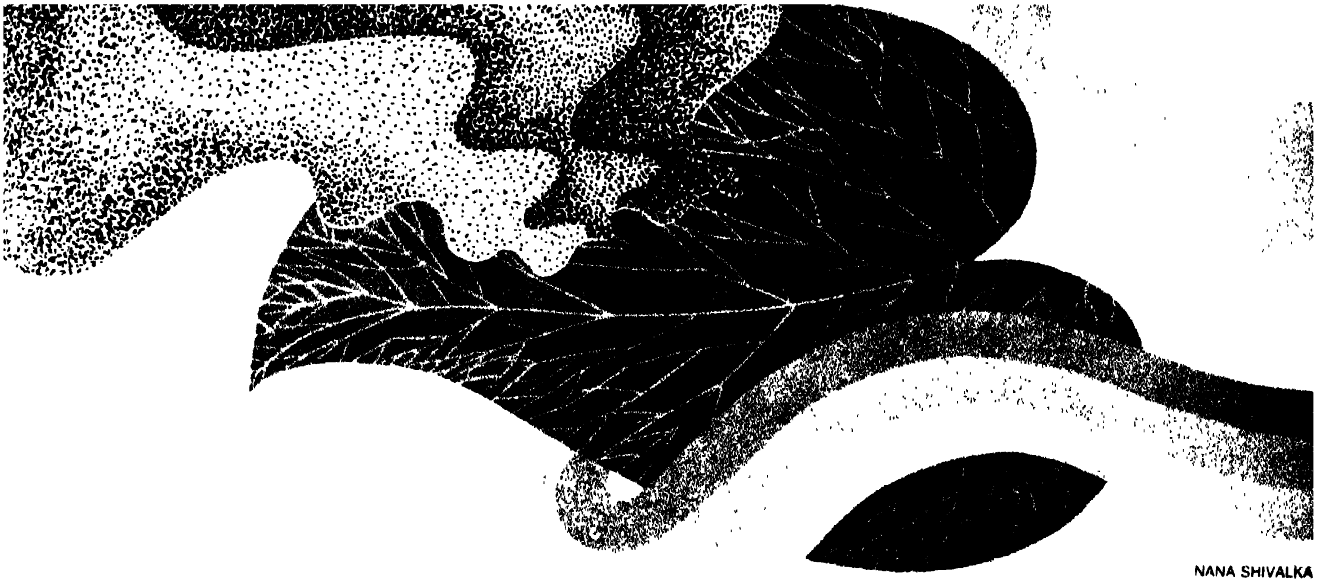


NANA SHIVALKA

TREES AS DUST-FILTERS

T M. Das, A. Bhaumik, A. Ghosh and A. Chakravarty

By filtering dust, trees and grasses help keep the air clean. But, there is a threshold limit

DUST has been known to travel several thousands of miles, across deserts and seas. Airborne particles of the Saharan sands cross the Arabian Sea and reach India. Though dust particles provide nuclei for cloud formation, they can be a nuisance to certain industries requiring aseptic and clean environment, like the different chemical and microbiological units manufacturing drugs and food processing plants. They can also be a health hazard at times. Recent research indicates that dust particles can lead to allergic ashtma, bronchitis, emphysema and even fibrosis of the lungs.

Many experiments have been designed to record dust pullution levels inside and outside green areas. For Hyde Park, a square-kilometre green area in the heart of London, an average of 27 per cent reduction in smoke concentration has been found. A study in the Soviet Union was set up to find out which tree genera exert the maximum filtering effects. For this purpose, dust per unit area of leaf surface was weighed. The results showed that the best vegetative dust filters were lilac with 2.33 grams per square metres of leaf surface (g/m^2); maple with 1.11 g/m^2; linden with 0.61 g/m^2; and poplar with 0.26 g/m^2. It was found that 400 poplars, the poorest dust collectors in the above study, could still filter out 0.375 tonne of dust in the leaf-bearing season.

Air is a strange mixture of oxygen, nitrogen, carbon dioxide, water vapour, traces of other gases and solid particulate matters. A huge quantity of fine solid particles of diverse chemical nature always remains suspended in the air. Air is also the natural medium for dispersal of spores, pollen grains, mycellia, bacteria and viruses. When an air current passes through a tree, some of the solid suspended particles adhere to the upper or lower surface of leaves, others are bounced back and become air borne again or get deposited at the base of the tree, depending on the size, physical-chemical character of the particle, velocity of wind and the nature of the surface of contact.

To estimate the dust-filtering capacity of different avenue trees, a study was carried out at the Pollution Research Laboratory, College of Agriculture, University of Calcutta. The leaves of different species growing in the same area and approximately of same age were carefully collected. Deposition of dust per unit area of the leaf surface was measured by removing the dust particles from the upper as well as lower surface of the leaf with the help of very clean, camel hair brushes and using a chemical balance (electrical) which weighs up to the fourth decimal place.

Obviously, ever-green trees with smooth or hairy leaf surface, like mango or fig, are better dust collectors than deciduous trees with compound leaf, like margosa or Indian laburnum. Simple leaves are better as dust collectors than compound leaves. In this regard peepal (*Ficus*), mango (*Mangifera*), teak (*Tectona*) and mast (*Polyalthia*) are better dust collectors than the flame of the forest (*Butea frondosa*) and gold mohur (*Poinciana regia*). The upper surface of the leaf collects most of the dust particles, but the lower surface also collects an appreciable amount. Though the compound leaves or needle-shaped leaves of pines are rather poor dust collectors, these leaves exert a significant filtering effect when an air current passes through their dense foliage. They act like a sieve, separating the suspended particles of the air by offering physical obstruction.

The dust sample collected from the leaf surface of avenue trees also has been subjected to chemical analysis. Major and micro nutrients of plants, like nitrogen, phosphorus, potassium, calcium, magnesium, iron, manganese, copper and zinc as well as toxic chemicals like aluminium, cadmium, arsenic and lead have been found. The former are known to play a significant role in the metabolism of the tree, though the toxic chemicals may have adverse effects on plants.

Dust absorption by grasses

Unlike leaves which have a distinct top and lower surface, monocotyledonous plants like grasses including cereals have erect (isobilateral) leaves. Consequently, a considerable amount of solid particles falling on the leaves, slide down and get deposited at the base of the leaves, where copious and numerous unicellular hairs—auricular hairs—are present (Figs. 1, 2). Microscopic observation reveals a dense accumulation of dust particles on the surface of these hairs. It seems that these unicellular hairs absorb water and salt solution. This can be easily demonstrated under the microscope by mounting a microscopic section of the leaf base on a slide and then adding a drop of water or colouring matter like neutral red with 0.005 molar calcium chloride solution to the tip of the hair. These hairs act like needles of hypodermic syringes, and suck the water or colouring matter very rapidly. Gaseous exchange also takes place through these hairs, which is revealed by the appearance of air bubbles in the liquid column inside the hairs. When the hairs were treated subsequently with calcium chloride solution and oxalic acid, crystals of calcium oxalate formed inside the hairs, indicating the uptake of both

Peepal *(Ficus religiosa)* with jarul *(Lagerstroemia flosreginae)* in background

An Indian avenue tree, gold mohur or gul mohur—*Poinciana regia*, is a common road-side tree.

Table 1: Dust filtering efficiency of different avenue trees. Samples were collected from Indian Botanic Garden, Shibpur, Howrah.

	Dust per sq m on upper leaf surface (grams)	**Dust per sq m on lower leaf leaf surface (grams)**	**Total dust per sq m on leaf surface (grams)**
Trees with simple leaf			
Ficus religiosa L. Peepal (Aswatha)	2.56	1.59	4.15 ± 0.07
Ficus infectoria Roxb Pakur	2.64	1.45	4.09 ± 0.08
Ficus benghalensis L. Banyan	2.71	0.88	3.59 ± 0.06
Tectona grandis L.f. Teak	4.10	1.25	5.35 ± 0.12
Shorea robusta Gaertn. Sal	3.40	1.10	4.50 ± 0.09
Terminalia arjuna Bedd. Arjuna	3.25	1.24	4.49 ± 0.10
Polyalthia longifolia Benth & Mast, Debdaru Hook	3.92	0.64	4.56 ± 0.09
Mangifera indica L. Mango	2.50	1.55	4.05 ± 0.06
Lagerstroemia flosreginae Ritz. Jarul	2.82	1.22	4.04 ± 0.03
Bauhinia purpuria L. Kachnar	2.70	1.20	3.90 ± 0.13
Anthocephalus cadamba Miq. Kadamba	2.42	1.15	3.57 ± 0.08
Thespesia populnea Soland Tulip tree	2.82	0.71	3.53 ± 0.07
Trees with compound leaf			
Saraca indica L. Asoka	2.56	1.22	3.78 ± 0.08
Butea frondosa Roxb. Flame of the forest (Palas)	2.20	0.85	3.05 ± 0.14
Azadirachta indica A. Juss Margosa (Nim)	2.20	0.72	2.92 ± 0.13
Cassia fistula L. Indian laburnum, (Sondal)	1.82	0.42	2.24 ± 0.09
Tamarindus indica L. Tamarind	1.56	0.52	2.08 ± 0.08
Poinciana regia Bojer (Syn. *Delonix regia* Raf.) Gold mohur (Gul mohor)	1.12	0.32	1.44 ± 0.07

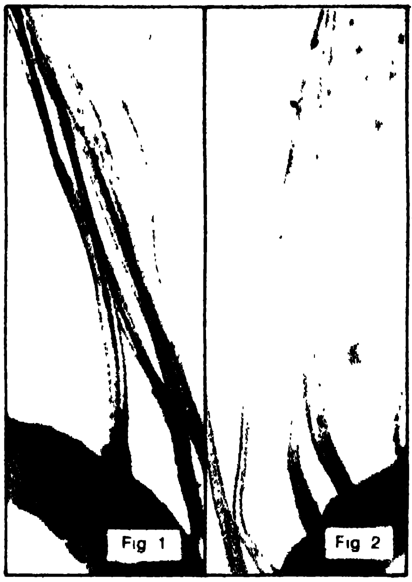
Figures are average per ten replication

the solutions by these hairs. Hence, the carbonic acid which is formed from water and carbon dioxide during plant metabolism helps to dissolve and ultimately absorb some chemicals accumulated at the leaf base

Microscopic studies of the leaf surface, after heavy spraying with dust particles on rice plants, also revealed that the deposition of particles on the leaf surface was not uniform. Particles were concentrated heavily on the stomatal pores (small pores on the leaf epidermis of higher plants through which exchange of gases and water vapour takes place) and thinly outside the pores. A large quantity of air continuously enters into the plant through these stomatal pores. If the air is not clean and contains dust particles of various sizes, obviously particles larger than the diameter of the stomatal pores tend to pile up on the orifice of the pores and interfere with the gas exchange. This in its turn may affect photosynthesis, water relation, respiration and the overall growth of the plant. This may also produce various deleterious effects on the normal physiological functions of the plants. Ultimately, the particles may even enter the leaf by dissolving in water and carbonic acid, discharged at the stomata. As the chemical nature of particles is extremely diverse, a series of synergistic reactions may occur among these particles affecting the physiological functions of the plant in a more complicated way.

The problems of air pollution are not new; both plants and animals have several adequate built-in mechanisms to encounter it. The evolution of ciliated epithelium, the protective lining covering the respiratory passages of higher animals, the nostril hairs and the structure of nose in man are a few of such adaptive mechanisms. Grasses are considered as a highly evolved groups of plants that appeared at the later stage of evolutionary history and by that time the atmosphere of the world had already been polluted. They are more resistant to adverse environmental conditions, and have adapted to exploit the polluted condition of the air to some extent. The auricular hair of grasses, acting as an adaptive organ, absorbs some amount of the major and micro nutrients from air. The erect structure of the leaf further increases the efficiency of this organ. Perhaps, these adaptive mechanisms evolved due to the intense selection pressure induced by the pollutant itself.

A popular Indian avenue tree— Indian laburnum (sondal)—*Cassia fistula*



Photomicrographs of auricular hairs of rice plants showing deposition of dust particles

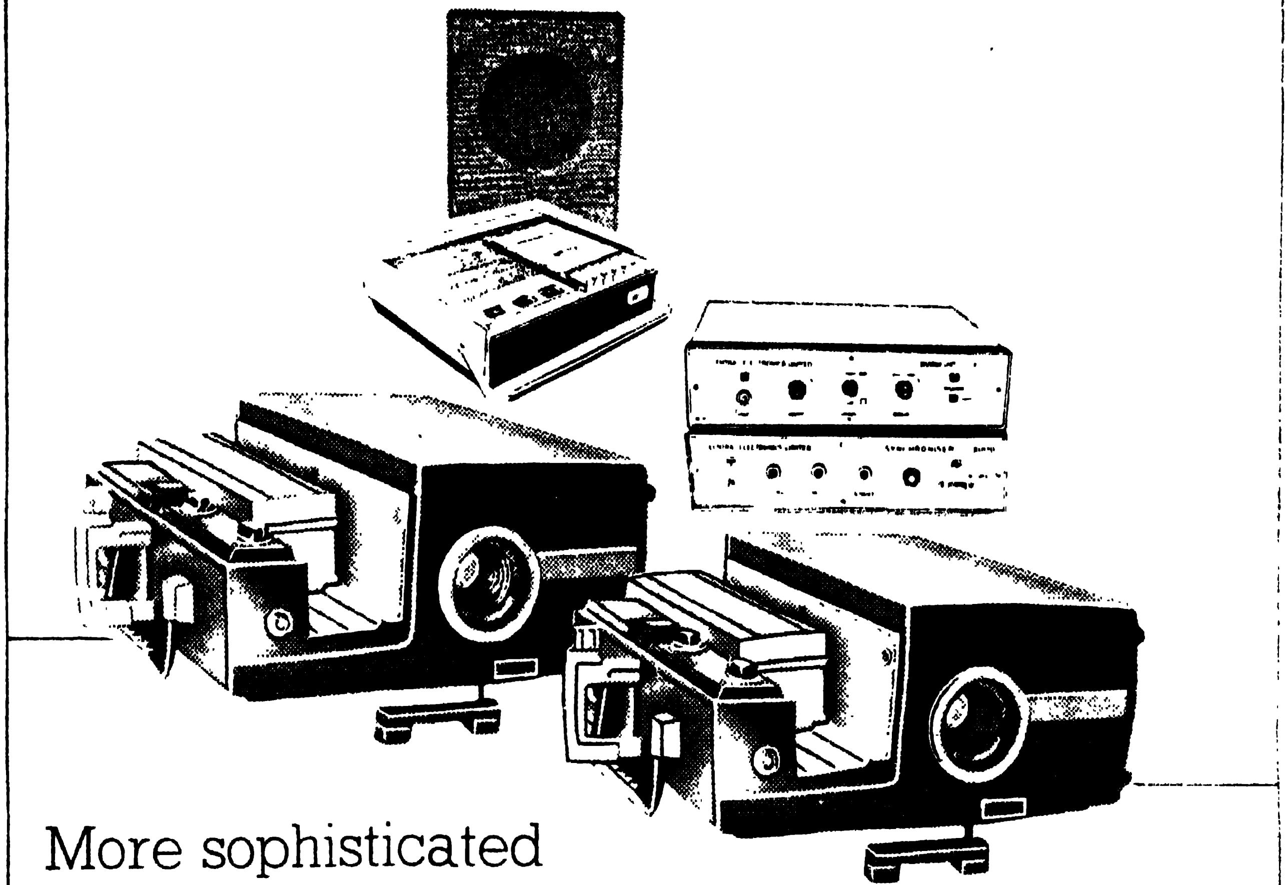
A common orchid

A parallel example of the utilisation of polluted condition of the air by the plant can be cited from orchids. Orchids are also highly evolved plants and appeared at a more recent period of evolutionary history. *Orchidaceae* family with its 25,000 species comprises the largest family among the flowering plants. Most of the members being epiphytes, they grow non parasitically on other plants but collect all their major and micro nutrients from the air. Epiphytic habit is also present in some members of pineapple family (*Bromeliaceae*) and arum family (*Aroideae*) as well as in some epiphytic ferns, like *Platycerium hillii*. If the air of the ancient world were perfectly clean, perhaps these epiphytes would not have evolved. Alternatively, we would have some other plant forms.

The grasses, epiphytes and tall trees, by offering various self-cleaning mechanisms, have been maintaining the purity of air through ages, and thereby maintaining the balance of nature. But the self-cleansing mechanism has always some definite threshold limit. At some degree of accumulation of toxic chemicals in the plant, the self-cleansing powers are exhausted. It is, therefore, left to us to find out these threshold values with different species of plants for different pollutants and their synergistic effects on various physiological functions. Researches on this line would help us to formulate the strategy of survival of life on an infinite time scale.

Dr. Das is Professor of Plant Physiology, College of Agriculture, Calcutta University. He has been working on the effects of pollution on plants for the last ten years

Mr Ghosh, Mr Bhowmik and Mr Chakravarti are the research associates of Dr Das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Stellar Rotation

L. Mestel and R. C. Smith

Young stars rotate faster than the old ones, but there are some puzzling exceptions

THE standard theory of stellar structure and evolution assumes that stars are spherical and so non-rotating. The theory has been reasonably successful in explaining the general features of normal stars. In a plot of luminosity against surface temperature the Hertzsprung-Russell diagram (p 24) —most stars are found to lie on a narrow strip called the *main sequence*, with the hot (early-type) stars being more luminous than the cool (late-type) stars. Stars are believed to spend most of their lives on the main sequence, converting hydrogen to helium in the central regions. The other main group of stars the giants—arise naturally from the evolution following exhaustion of the central hydrogen.

However, ever since Galileo picked up the motion of sunspots in his telescope, we have known that the Sun rotates, though it was nearly three hundred years before the rotation of other stars was detected. It is now believed that all stars have some rotation. The evidence comes primarily from the Doppler broadening of spectral lines. This transforms a deep narrow line into a saucer shape (Fig 1) so enabling us to infer $V \sin i$ where V is the equatorial rotation speed and i is the inclination of the rotation axis to the line of sight. As V and i cannot usually be found separately, information about the distribution of V—for example between stars of different type—has to be statistical (on the assumption that the rotation axes of stars are randomly oriented in the sky). (However, ultra-violet spectra of hot stars obtained recently from satellites show that rotational broadening decreases at short wavelengths, and theoretical interpretation of this effect may enable separate determination of V and $\sin i$.)

The most striking broad generalisation that emerges is the much higher mean V for early-type than for late-type stars (Fig. 3). The effect is strongest for main sequence stars, but normal cool giant stars also show lower rotations than hotter stars. The physically significant quantity—the angular momentum per unit mass—shows a sharp break on the main sequence at about 1.5 solar masses, coinciding approximately with the transition from stars with strongly convective envelopes (low mass) to those with stable envelopes, with radiative energy transport dominating (see box on p 26).

Stars with an essential departure from axisymmetry enable us to measure directly the angular velocity $\omega = 2\pi/T$, where T is the period of the non-axisymmetric feature. The early-type strongly magnetic stars show variations in the Zeeman splittings of their spectral lines that are periodic, though not sinusoidal. These variations are most easily interpreted in terms of the *oblique rotator* model (Fig. 4) with a magnetic field "frozen" into the highly conducting stellar gas and so rotating with the star, but with the field axis inclined to the rotation axis. These stars are a sub-class of the Ap—"peculiar A"—stars: the same periodicity is picked up in the spectrum and luminosity. With the radius estimated from the luminosity and surface temperature, the rotational velocity is then calculated. It is found that these stars rotate significantly more slowly than the normal A stars: periods of 5 or 10 days are typical, as compared with an inferred mean period $T = 2\pi R/V$ of about a day for the normal A stars of radius R. There is even a hint that some pulsating stars may be oblique rotators. The star RR Lyrae, the prototype of the short-period variables typically found in globular clusters, shows a modulation of the luminosity and velocity curves over a period of several weeks. This may be explic-

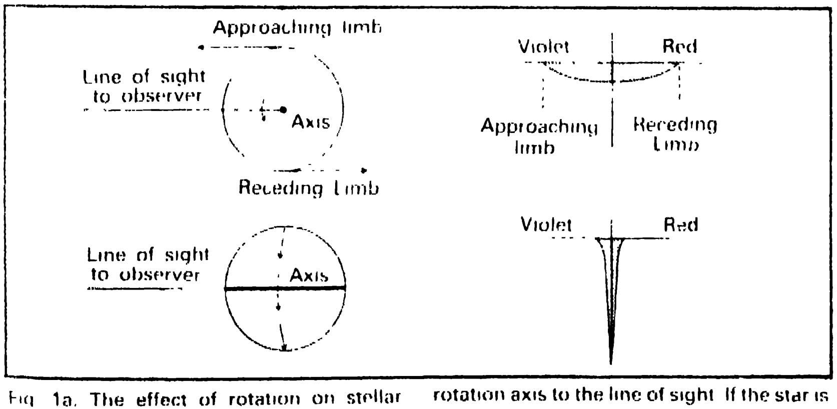
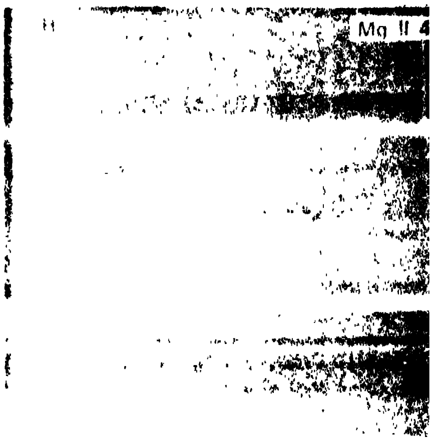


Fig 1a. The effect of rotation on stellar spectra is to broaden the spectral lines. If a star rotates, radiation emitted from the part of the surface moving towards the observer is blue-shifted whereas the radiation from the receding surface is red-shifted. Since the observer sees the surface from the whole disc of the star, the observed spectral line is broadened by an amount depending upon the inclination of the rotation axis to the line of sight. If the star is rotating with its axis perpendicular to the line of sight, maximum widening of spectral lines occurs. Since the line broadening depends upon the total difference between the equatorial velocities at the approaching and receding limbs, no broadening is seen if the rotation axis is along the line of sight as the equator of the star is then in the plane of the sky



Sky and Telescope

Fig 1b These three spectra of A2 stars show the effects of rotation on stellar lines. The projected equatorial rotation velocities of Theta Leonis (top), Theta Andromedae (middle) and Gamma Ceti (bottom) are 0, 125 and 195 km per sec, respectively. The effect is best seen in the intrinsically narrow Mg II line

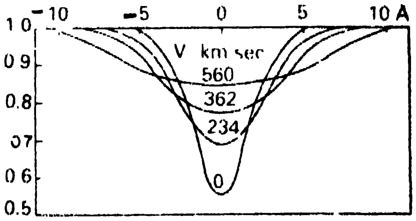


Fig 1c The spectral line in a non rotating star is relatively narrow and is about 10 A wide. For rotations of 234, 362, 560 km per sec the line is broadened more and more and becomes shallower and shallower (less intense at the centre)

Tassoul Theory of rotating stars

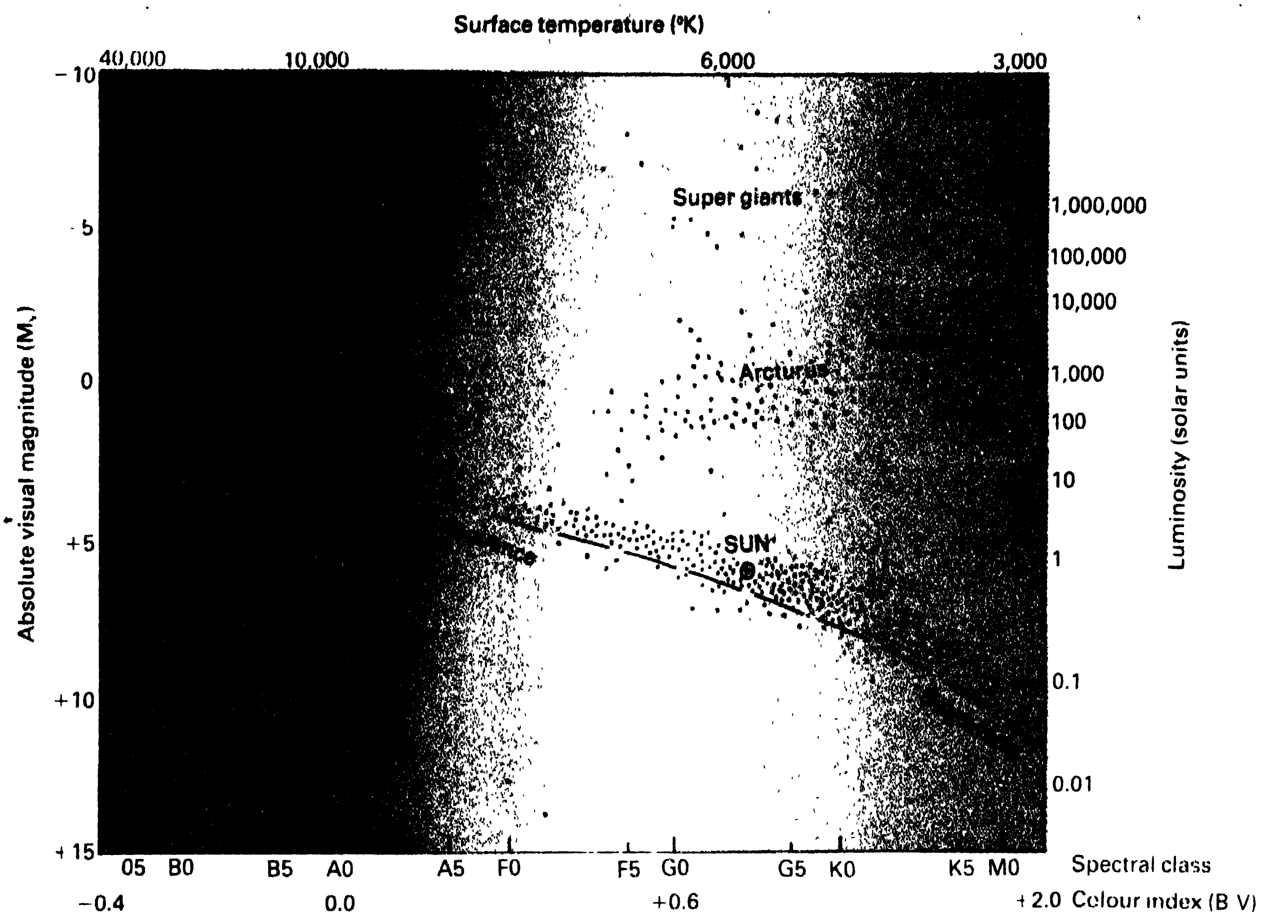


Fig. 2. The Hertzsprung-Russell (HR) diagram is a plot showing the relation between luminosity and surface temperature of stars The other related quantities frequently used are the absolute magnitude for luminosity and the spectral type or the colour index of stars for temperature The main feature of the diagram is that stars lie in well-defined regions. The great majority of stars lie in a band, running diagonally from upper left to lower right, known as the main sequence, and we deduce that all stars spend a large part of their life on the main sequence. During this time a star is essentially in equilibrium, with the energy radiated from its surface balanced by the energy generated by nuclear reactions in its interior, and its properties change only very slowly The range of luminosity and temperature along the main sequence is caused by stars having a range of mass the more luminous, hotter stars have systematically larger masses The time spent in the main sequence band ranges from a few million years for luminous stars on the upper main sequence to more than a few thousand million years for the lower main sequence stars. The other groups in the HR diagram—giants, supergiants and white dwarfs—also represent comparatively long-lived stages of a star's evolution White dwarfs represent a final stage of a star's existence when its nuclear resources are exhausted and it is slowly cooling They are faint because, although most of them have high temperatures, they are very small in size On the other hand giants are cool but enormous and so are highly luminous. Supergiants are rare but are even larger and more luminous than the giants Both giants and supergiants represent an intermediate stage between main sequence stars and stellar remnants like white dwarfs.

Stars are born from huge interstellar clouds of gas and dust (see SCIENCE TODAY, April 1981, p. 35) These clouds collapse under their gravitational fields and form protostars As the protostars contract, the gravitational energy is used to heat the interior and to supply energy for radiation escaping from the surface. Finally the internal temperature becomes so high that hydrogen burning into helium begins to supply the radiating energy. This defines the zero-age main sequence (ZAMS). T Tauri stars are thought to be stars in the pre ZAMS phase of evolution. The main sequence stars convert hydrogen into helium to maintain their energy balance

When all the hydrogen in the core has been converted into helium, the outer envelope—which retains its original composition—expands rapidly and the star moves quickly to the right of the main sequence and becomes a red giant star What happens next depends on the initial mass of the star and on how much mass it has lost, for example by stellar winds Stars with final masses less than about 1 4 times the solar mass probably end up as white dwarfs, with mean densities of about a ton per cubic inch Slightly more massive stars up to a maximum mass of about two solar masses, can end up as even denser stars, called neutron stars, with a radius of only 10 kilometres Rapidly rotating neutron stars which have very strong magnetic fields (of the order of 10^{12} gauss) rigidly linked to the surface are supposed to emit radiation which arrives on the Earth as pulses with a very high degree of regularity. Such stars are called pulsars

able in terms of the back-reaction of a periodically distorted magnetic field, with the long period variation just a manifestation of changing aspect of an oblique field as the star slowly rotates.

The pulsar is probably the most spectacular example of the oblique rotator. After the discovery of the pulsar in the Crab nebula, with its period of 1/30 sec, it was clear that the basic clock could hardly be anything other than the rotation of a neutron star. The only other candidate—a white dwarf, typically with a mass close to the Sun's, and a radius comparable with the Earth's—when rotating at this frequency would feel a centrifugal force some 10^{5} times its self-gravitation; whereas for a neutron star with a radius of 10 kms, the ratio would be about 10^{-4}. (It is remarkable that we should have to describe this exotic body with such a short rotation period as a "slow rotator", but this non-dimensional number is the only meaningful measure of "fast" or "slow"). Again, we pick up the periodicity because of an asymmetry—the obliquity of the axis of the magnetic field which is presumably essential for the beaming of the radiation that we receive.

Origin of stellar rotation

It is hardly surprising that stars do rotate. A blob of interstellar gas from which a star forms will certainly have a net angular momentum about its mass-centre, and if the blob were to conserve its angular momentum during its contraction, the centrifugal forces of spin would increase more rapidly than the self-gravitation of the blob. In fact, if we adopt realistic values, we are forced to invert the question, and ask rather how it is possible for the blob to reach anywhere near stellar densities before centrifugal forces become so large as to interfere with the contraction. Plausible answers can be found, for example, it is likely that during the early stages of star formation, the torques exerted by the galactic magnetic field that threads the protostellar cloud transfer most of the initial angular momentum into the surrounding gas. Even so, the remnant angular momentum should still be high. Could it be that all stars reach the main sequence as rapid rotators, but the cooler stars subsequently suffer continual efficient braking?

In the case of the Sun we have direct evidence from satellites. The hot solar corona drives the solar wind which streams past the Earth with highly supersonic speeds, and transports away per second much more angular momentum than that carried by the gas as it leaves the solar surface (Fig. 5). This is again due to magnetic coupling: as long as the wind speed is below the Alfvén speed (the speed of quasi-elastic waves—"Alfvén waves"—along magnetic field-lines), the magnetic torques keep the gas more or less corotating with the Sun. The convective envelope is crucial. It generates the waves which propagate upwards to be damped, so maintaining the high coronal temperature; and it is the locale of the dynamo process which is presumably responsible for the superficial solar magnetic field. Studies of line broadening in late-type stars in the young Hyades and Pleiades clusters show that rotation is indeed a decreasing function of age (Fig. 6).

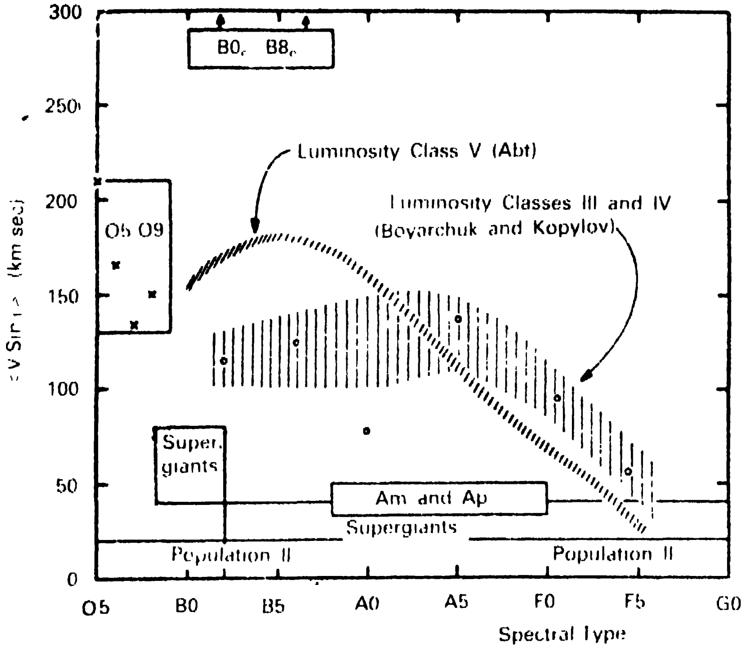


Fig. 3 Dependence of rotational velocity on spectral type, taken from catalogues by Abt and by Boyarchuk and Kopylov. Luminosity class V stars are main sequence stars and luminosity classes III and IV are giant stars. Note the rapid decrease of rotation velocity towards later spectral type. The Sun—a G2 star—has a rotation speed of only 2 km per sec, and this is typical for single late-type stars with deep convective envelopes. It is believed that these envelopes are responsible for mass and angular momentum loss from late-type stars, which probably started their lives spinning more rapidly. Late-type stars in binary systems retain their rapid rotation because of the tidal influence of their companions.

Although normal A stars rotate fairly rapidly, most peculiar stars like the metallic-line Am stars and the magnetic Ap stars rotate slowly. The reason for this is not clear. Giant stars rotate more slowly than normal main sequence stars while supergiants in general show little or no rotation. This is probably simply a result of conservation of angular momentum as the stars expand away from the main sequence.

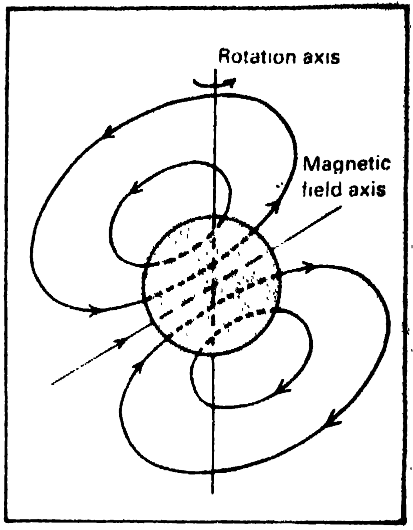
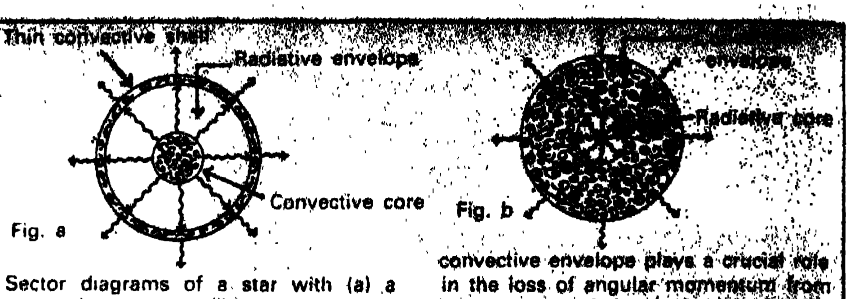


Fig. 4 In an oblique rotator model, the star is assumed to have a magnetic field with its axis inclined to the rotation axis. Due to the presence of the magnetic field, lines in the radiation spectrum from the stellar surface are split into components by the so-called Zeeman effect. The observed magnetic field strength depends upon the angle between the line of sight and the field axis and is modulated as the star rotates because areas of different field strength pass in front of the line of sight. If different regions of the surface have different compositions, then the spectrum of the star varies as the star rotates. If the magnetic field is static, that is, frozen into the star, then the magnetic field strength and the spectral variabilities are periodic.

Indirect supporting evidence comes from the decline of calcium activity with age, for this is a measure of the strength of the dynamo-built magnetic field, which is expected to decline with loss of angular momentum. However, plausible extrapolation back to the epoch when the Sun arrived on the main sequence, using the evidence from the young clusters, yields a "zero-age" Sun rotating certainly much faster than at present—by a factor ten or twenty—but still with the centrifugal force much less than the gravitational force.

The result focusses attention on the pre-main sequence phase of stellar evolution. Perhaps all stars—opaque self-gravitating bodies in hydrostatic equilibrium—did indeed form as rapid rotators but during the slow contraction to the main sequence (at a rate regulated by radiation loss), further angular momentum redistribution occurs. The less massive stars may possibly suffer excess braking through a strongly enhanced stellar wind, driven by the violent turbulence predicted by C. Hayashi. A star which still retains too much angular momentum for comfort may try and resolve the problem by the permanent conversion of spin angular momentum into orbital, for example

What are stars?



Sector diagrams of a star with (a) a convective core, and (b) a deep convective envelope. High luminosity stars with high surface temperatures have convective cores, whereas all stars with surface temperatures below 7500°C, type F2, have convective envelopes. The Sun has a convective envelope of depth intermediate between those shown. The outer convective envelope plays a crucial role in the loss of angular momentum from rotating stars. It is responsible for the emission of gas as a stellar wind, and is the seat of the dynamo generation of the stellar magnetic field which couples with the wind so as to brake the star's rotation. Stellar magnetic activity—analogous to the 22-year sunspot cycle—has been detected in other late-type stars.

A STAR is a gaseous body held together by the mutual gravitational attraction of its constituents. If only gravitational force existed, the star would collapse, but there is also the pressure due to the thermal motions of its constituent electrons and ions and the photons trapped within. When pressure and gravitation balance everywhere, the star is said to be in hydrostatic equilibrium. If the two forces are out of balance, the star will expand or contract. Stars are in hydrostatic equilibrium for most of their lives.

Radiation is continuously emitted from the stellar surface, and the fact that the surface does not cool down rapidly indicates that there must be some internal source of energy which compensates for the radiational losses. Over most of a star's life, energy is generated by nuclear reactions (conversion of hydrogen into helium) in the stellar core and is transported to the surface. The luminosity (L)—energy radiated per second from the stellar surface—depends upon the size and the surface temperature (T). If R is the stellar radius, L is directly proportional to R^2T^4.

How is this energy transported to the surface? There is a temperature gradient between the core and the surface, and in a typical star energy is transported mainly by radiation and convection. The time taken for energy to diffuse from the centre to the surface of a star is known as the thermal or Kelvin-Helmholtz timescale. This depends upon the opacity—a measure of the resistance of the material to the passage of radiation. Above a critical value of the temperature gradient, radiation alone cannot cope with the energy to be transported, and convection sets in. In high luminosity stars with high surface temperatures, convection occurs in a *convective core*, an extended region about the centre (Fig. a). Transport of energy from the core to the surface is primarily by radiation. In cooler stars, such as the Sun, convection occurs in a surface shell—a *convective envelope* (Fig. b)—carrying the bulk of the energy to the surface, where it is radiated away. Radiation is the main mode of energy transport in the energy-producing core of these stars. Convection is an efficient mixing mechanism, and so the chemical composition of a convective zone remains uniform. In radiative regions composition gradients may arise as a result of nuclear reactions, but they will be localised to regions of high temperature (except possibly for the effects of the very slow mass motions that may arise in rotating stars).

The outermost layers of a star with a convective envelope are heated by energy deposited by waves generated in the envelope. This heat produces the chromosphere, the corona, and the stellar wind. The presence of a chromosphere in the Sun and other solar-type stars is inferred from CaII emission (characteristic spectral line emission from calcium atoms which have lost an electron). This emission is particularly strong in regions of strong local magnetic field strength.

Some special types of stars

Variable stars show varying luminosity. In some the variations are periodic, in others they are irregular. The regular variables include the Cepheids, with their well-known period-luminosity relation which makes them so useful as distance indicators. The short-period variables, with periods of the order of half a day, are called RR Lyrae variables after their prototype. In both Cepheid and RR Lyrae variables, the luminosity variations are due to the star's pulsating regularly.

Among the irregular variables are the T Tauri stars, which show spectral evidence for heavy outflow of matter from their surfaces. They are probably *protostars*—stars in the later stages of formation

Magnetic stars. Strong magnetic fields, of the order of 1000 gauss or more, have been observed on the surfaces of many stars. Compare this with the Sun's average surface field of about 1 gauss. Magnetic fields are discovered *via* the Zeeman effect—the splitting of spectral lines in the presence of a magnetic field. The magnetic fields show variations which are normally periodic or cyclic, indicating that the stars are oblique rotators (Fig. 4).

Most stars with strong magnetic fields are peculiar A (Ap) stars, though strong magnetic fields have now been found in some early-type main-sequence stars and in some white dwarfs. The abundances of certain elements, mainly manganese, silicon, strontium, chromium and europium are far greater in the surface regions of Ap stars than in normal stars of similar spectral colour. The peculiarities are not distributed homogeneously over the surface, and so the spectral lines also change periodically as the star rotates.

The spectral types of normal stars

Stars can be divided into a number of classes depending upon their spectral characteristics. These classes are denoted by capital letters OBAFGK and M, and are based on the elements that appear to be most prominent in the spectra. The appearance of the spectra depends far more upon the surface temperature than upon the actual relative abundances of the elements on the surface. Most normal stars have essentially the same surface composition as the Sun. The above order of spectral classification is based on decreasing surface temperature. The blue stars are classified as O and the cooler stars are of M spectral type. Each class is further subdivided into ten sub-classes ranging from 0 to 9, in order of decreasing temperature, except O which goes from 3 to 9.5. The amount of light received on unit area at the Earth's surface from a star is expressed in logarithmic units called magnitudes, the brightest star having the lowest magnitude. The absolute magnitude of a star is defined as the apparent magnitude the star would have if it were placed at a distance of 10 parsecs (1 parsec $= 3.09 \times 10^{16}$m $= 3.26$ light years). The absolute magnitude of a star depends upon its mass, chemical composition, temperature and age, that is, the time elapsed after it was formed. This relationship can be well studied if one plots stellar absolute magnitude versus spectral type. Since the variation in spectral types arises from variation in temperature, and in turn the colour of stars are related to their surface temperatures, one can equally well plot absolute magnitude against the colour index (Colour index is the difference between the magnitude of the star in two wavelength bands). The most commonly used wavelengths are ultravioler (U), blue (B) and visible light (V). Such a diagram is known as the Hertzsprung-Russell (HR) diagram (Fig. 2).

by the formation of a binary pair, or of a planetary system such as our own, where Jupiter has only one thousandth of the mass, but its orbital motion about the Sun carries most of the angular momentum of the whole solar system (see the article in last month's Science Today p.30).

Rotation and stellar structure

What effect does rotation have on stellar structure? A star is basically a body held in equilibrium against its self-gravitation by gas pressure. In non-collapsed stars the gas obeys closely the classical gas law, and hydrostatic support requires a high internal temperature, with a consequent leak of radiant energy to the surface—the stellar luminosity, calculable in terms of the opacity of the stellar gas. In a rotating star the centrifugal forces modify this equilibrium, but for the body to remain describable as a star the centrifugal effects should be "perturbations" (though not necessarily small perturbations) of a basic state of pressure-gravitational balance. The centrifugal force may nearly balance gravity locally as for example in the atmospheres of some hot stars which show emission lines, but over the bulk of the star we expect centrifugal force at most to be comparable with pressure. Note the contrast with a disk-like galaxy, where the "pressure" defined in terms of random stellar motions is a perturbation of a basic centrifugal-gravitational equilibrium; or with the "accretion disc" surrounding neutron stars in current models of x-ray sources, where again thermal pressure is a perturbation

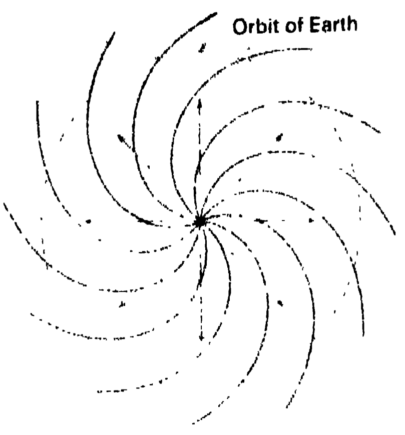
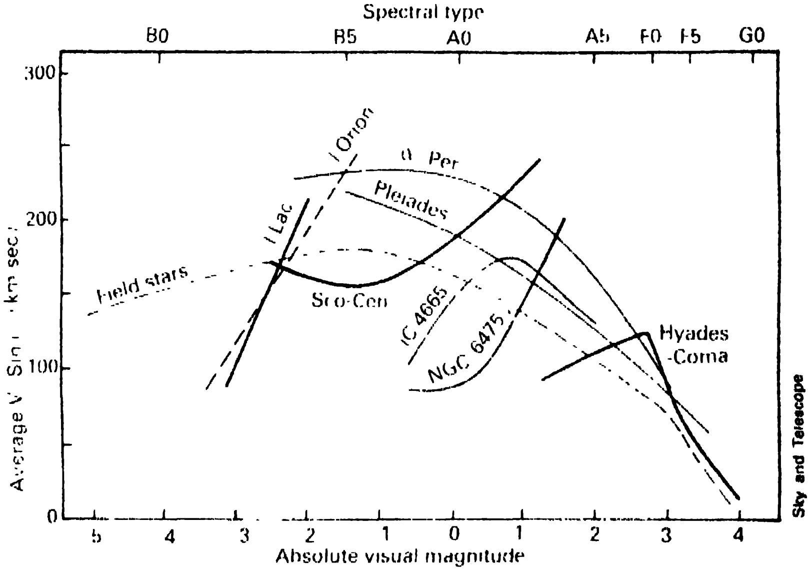


Fig 5 Continuous emission of matter from the solar surface draws out with it the solar magnetic field lines into interplanetary space. If the Sun did not rotate, the solar wind would simply pull out the magnetic field lines radially. However, since the Sun does rotate, the outflowing gas particles trying to conserve their initial angular momentum, lag behind the rotating Sun, and so distort the field further into a spiral pattern. The stresses of the distorted field exert a braking torque on the star and transfer angular momentum to the outflowing wind. By the time that the particles break off from the magnetic field, they have a much larger angular momentum than when they left the Sun and so even the small rate of mass loss from the Sun yields a large rate of angular momentum loss

Since the gross effect of centrifugal force is to assist pressure in opposing gravity, a rotating star will crudely mimic a non-rotating star of lower mass: lower central temperature, higher central density and lower luminosity. The essential anisotropy of centrifugal force causes the star to flatten: the equatorial radius of a uniformly rotating star can increase by up to fifty per cent (to the point of centrifugal balance at the equator), while the polar radius decreases slightly (Fig. 7). This flattening leads to brightness variations over the surface. Thus the position of a star in the Hertzsprung-Russell diagram should change by an amount depending not only on the angular velocity but also on the inclination of the rotation axis to the line of sight. Because of the central condensation of mass in real stars, the mean ratio of centrifugal force to gravity is only a small percentage if the star rotates uniformly, but even so the effects are not negligible. Thus for example, a young star cluster such as the Hyades would be assigned an age that is seventy per cent too great, if the displacement of the stars in the H-R diagram due to uniform rotation were supposed, instead, to be due to normal nuclear evolution. If stars are supposed to rotate more rapidly deep down, so that centrifugal forces remain comparable with gravity throughout the star, then considerably greater effects result. Extensive numerical computations show that the changes in central temperature and density and in luminosity depend essentially on the total angular momentum of the star, and only weakly on the details of its distribution. A reduction in luminosity by a factor four is possible.

Attempts are continually being made to infer from the H-R diagram whether or not stars rotate significantly non-uniformly, but no unambiguous conclusions seem as yet to have resulted. Many other workers are intrigued by the hydrodynamics of rotating, self-gravitating bodies. A mass of gas in non-uniform rotation contains more kinetic energy than the same mass with the same total angular momentum but rotating uniformly; hence any dissipation of rotational energy through viscosity would *prima facie* tend to set up solid body rotation. However, in a stable.



Sky and Telescope

Fig. 6 Observations of stars in clusters and associations suggest that their rotation slows down with age. Stars belonging to the same cluster or association are supposed to have formed from a common interstellar cloud and have the same age. In the diagram, curves representing mean rotational velocity against luminosity for main sequence stars of stellar systems and field stars in our galaxy have been plotted. Though all close binary stellar systems have been included, the Ap and Am stars have been excluded here because they are atypically slow rotators. The following ages are in millions of years: Orion I association, 3, Scorpio-Centaurus association, less than 4; Lacerta I association, 7; Pleiades, 50, IC 4665, 60, Alpha Persei association, about 100, NGC 6475, about 100, Coma Cluster, 600, Hyades, 1,000. In general, stars in a younger cluster rotate faster than stars of the same spectral class in an older cluster. Curves for different clusters of the same age have different shapes suggesting different initial conditions in the interstellar clouds from which the stars were formed

radiative stellar zone, the viscosities arising from the random motions of ions and photons are too small to affect the rotation law over stellar lifetimes. Stability requirements impose important restrictions, for example, if the angular momentum per gram decreases away from the axis too strongly, then spontaneous adiabatic motions—without transfer of heat—will cause a rapid redistribution of angular momentum. When allowance is made for the slow but significant heat interchange between moving elements, then much more stringent conditions for *secular* (long-term) stability are found—for example, the angular velocity must be constant on cylinders about the rotation axis, the angular momentum per gram must not decrease away from the axis, and the total rotational energy must not exceed about ten per cent of the gravitational.

These restrictions still allow much greater centrifugal effects on stellar structure in a non-uniformly rotating star than in a rigidly rotating star. However, other processes may interfere. Even a stably stratified radiative zone may not be free from mass motions. A rotating star in general cannot satisfy strict local radiative equilibrium—the energy balance in a unit volume cannot be maintained by radiative processes alone. For example, if the star rotates uniformly, the resultant temperature distribution is such that an element of gas near the axis of rotation gains more heat by radiative transfer than it loses, whereas an element near the equator loses more than it gains. The consequent buoyancy forces drive slow, large-scale motions known as the *Eddington-Sweet* circulation, which can advect angular momentum through the bulk of a rapidly rotating star in a time close to the global thermal time (the Kelvin-Helmholtz time). Probably most important is the effect of a magnetic field threading the star. Even if the surface field is too weak to be detectable by the Zeeman effect on spectral lines, the bulk field can still interact decisively with the stellar rotation field. Non-uniform rotation twists the field-lines, which react by exerting a torque on the gas: this will redistribute angular momentum via Alfvén waves, in the time it takes for an Alfvén wave to cross the star. It can be argued that a star will retain quite enough magnetic flux from its formation epoch for this Alfvén time to be well below either a stellar evolution time—the lifetime of a star on the main sequence—or a Kelvin-Helmholtz time, so that near uniform rotation should be a better approximation. The same process will account satisfactorily for the low angular velocity of white dwarfs and pulsars: magnetic coupling would ensure that a gently contracting core steadily loses angular momentum to an expanding envelope.

Convective zones and magnetic activity

A different physical picture is appropriate for convective zones. Such turbulent zones are often crudely described as having an effective large isotropic viscosity, arising now from random motions of large-scale turbulent eddies. This would imply that turbulent zones would try to rotate rigidly, whereas in fact a modest but significant non-uniform rotation is observed on the solar surface. More subtle ways of describing the turbulence emphasise its essential anisotropy and non-uniformity: there must be a difference in the efficiency of transport of both momentum and heat between vertical and horizontal directions and between different regions of the zone. These studies do predict steady states with non-uniform rotation, and large-scale laminar motions superposed on the turbulence.

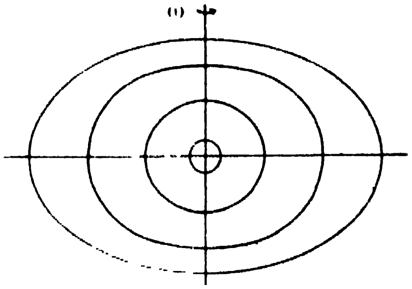


Fig 7 Non rotating stars are spherical in shape. But since they are gaseous, once they start rotating, they are flattened at the poles because of centrifugal forces. The surfaces of constant temperature, pressure and density are then not spheres but are approximately ellipsoids. Rapidly rotating stars are more flattened. The temperature gradient near the poles of the star is steeper than that near the equator and so the star is non-uniform in brightness. The luminosity of a rotating star is therefore dependent upon the inclination of the rotation axis to the line of sight

It is perhaps doubtful if these departures from uniform rotation are large enough to affect stellar structure significantly. However, non-uniform rotation is certainly crucial for dynamo action. It is the nuclear sources of the star which maintain the gross energy balance, and some of this energy is tapped to supply that stored in the non-uniform rotation of the convection zone. The first stage of current dynamo models is again the conversion of this energy into azimuthal magnetic energy by the action of the shear on an initial meridional field. The dynamo cycle is completed by the azimuthal field being distorted into a new meridional field by essentially non-axisymmetric mass motions. In order to produce an *oscillatory* dynamo, as observed in the Sun (the 22-year sunspot cycle), and inferred from periodic calcium activity in other solar-type stars, most theoretical workers require that the angular velocity should increase with depth.

We have earlier appealed to an expected increase with rotation of the strength of the dynamo-built field in order to interpret the observations of line broadening in stars of different ages. The *RSCVn close binary systems* show what appears to be greatly enhanced solar activity, with strong chromospheric, radio and x-ray emission, and evidence that a large fraction of their surfaces is covered by dark spots. This is again consistent with rotation being a crucial parameter for magnetic activity. Close binary systems have a large supply of orbital angular momentum. Tidal or magnetic coupling ensures close synchronisation between spin and orbital angular velocity, so that these late-type stars rotate rapidly; removal of angular momentum by a magnetically controlled stellar wind does not lead to a reduction of spin, but rather to a steady decrease in the mutual separation of the stars and an increase in their spin. The vital importance of rotation for our understanding of magnetic activity is thus clear, but we are still a long way from having a definitive dynamo theory which includes both the action of gas motions on the field and the back-reaction of the magnetic forces on the dynamics of the flow.

Braking of stellar rotation

The observational inference that normal early-type stars rotate rapidly implies that there has been no strong braking during their lifetime. Notable exceptions are the strongly magnetic stars, which we saw may be plausibly interpreted as oblique rotators. Whatever the origin of the magnetic fields—whether they are being maintained by contemporary dynamo action, or are slowly decaying "fossils", relics of an earlier phase in the star's life, or even of the galactic field—one can expect magnetic coupling between the star and external gas steadily to slow up the star's rotation. Strong stellar winds are perhaps not to be expected from these stars, and indeed the Einstein x-ray detecting satellite has failed to pick up evidence of a hot corona surrounding them. However, interstellar gas accreted by the star will also tend to be set into corotation by the magnetic field. As long as the "accretion radius", where the inflowing gas is halted by the magnetic pressure, is considerably greater than the stellar radius, the centrifugal force on corotating gas will exceed gravity, and the accreted gas will flow out, carrying off stellar angular momentum. The process has a natural cut-off when the star's angular velocity is low enough: the predicted rotation periods are of the observed order.

Magnetic braking is effective only as long as enough field-lines emerge from the star's surface. In a late-type star like the Sun, primeval magnetic flux may be present in the core, but prevented from emerging by the powerful turbulence in the envelope: it is the field built up by the superficial dynamo that is responsible for braking. In an early-type star, field-lines should initially emerge from the surface, but the Eddington-Sweet circulation present in a rapid rotator may steadily drag field-lines beneath the surface before significant magnetic braking has occurred. Likewise, in a rapid rotator the circulation currents may prevent or limit the development through diffusion of abundance anomalies. It is again significant that the Ap stars — whether observably magnetic or not — and the "metallic-line" Am stars are indeed slow rotators. Magnetic braking is not the only explanation: most Am stars are members of *moderately* close binary systems, so that spin orbit synchronisation enforces a fairly slow rotation. But whatever the cause, it appears that slow rotation is a necessary condition for the abundance peculiarities to develop, and a suggested reason is that in a rapid rotator the diffusion processes will be off-set by the effect of the Eddington-Sweet circulation.

To sum up, although rotation is not vital to our overall understanding of stellar structure it does make important and subtle changes in the detailed theory. Many of the problems are still to be resolved and stellar rotation remains an exciting and challenging field of research.

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Dr Smith, editor of *Observatory Magazine* since 1977, is presently a lecturer in astronomy, University of Sussex. He was educated in Glasgow where he obtained his Ph D in astronomy in 1968. His research interests are stellar rotation and hydrodynamics, binary stars and stellar winds.

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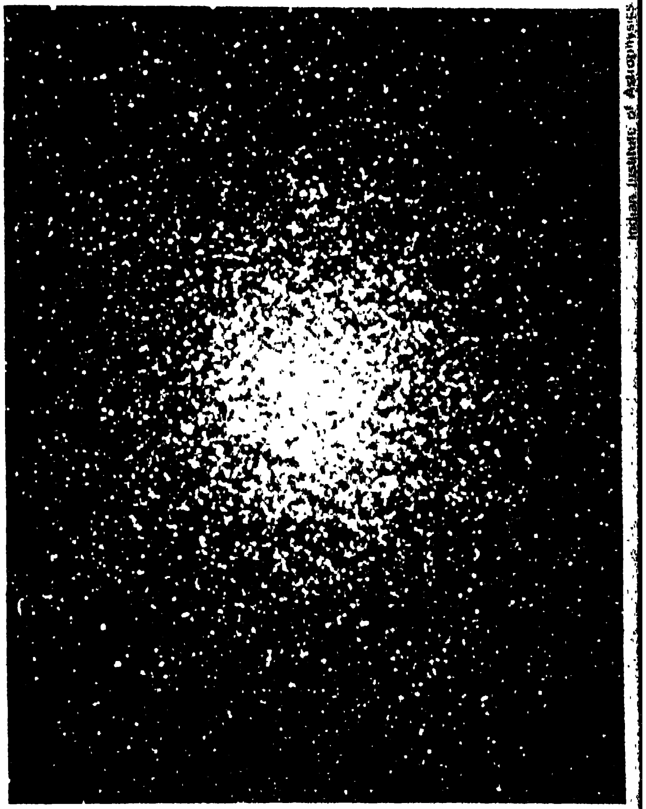
The Rotating Galaxy

Saleh Mohamed Alladin

Galactic rotations, closely related to their shapes, provide clues to the origin and evolution of galaxies

IN the beginning of the present century, it was believed that our star, the Sun, occupied a central position in the vast system of stars which, in the night sky, form the diffuse band of light we call the Milky Way. The Milky Way, also known as our galaxy, is just one of the billions of such huge star aggregates referred to as galaxies. Then, about 1917, a revolutionary discovery was made at the Mount Wilson Observatory in California, USA, by Harlow Shapely. He deduced from a study of the distances and motions of the globular star clusters in our galaxy (Fig. 1) that the Sun after all, did not occupy this privileged central position. It was actually situated far away from the galaxy's centre (Fig. 2). This was a big leap forward since 1543 when Copernicus dethroned the Earth from its privileged position, of being the centre of the cosmos, that it had enjoyed since antiquity.



Indian Institute of Astrophysics

Fig 1. Omega-Centauri—a bright globular cluster containing as many as 1,00,000 stars. Globular clusters are believed to be oldest of the known galactic objects

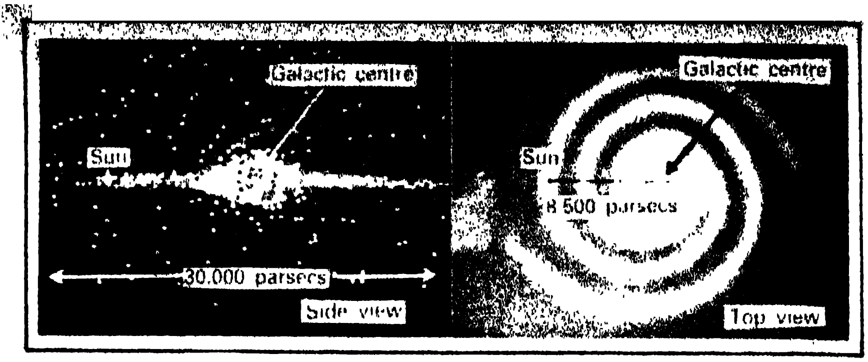


Fig. 2. The schematic model of our Galaxy shows that the Sun is at a distance of about 8.500 parsecs (one parsec = 3.26 light years = 3.1 × 10^{18} years) from the galactic centre. Most of the observable stars lie in that part of the galaxy which has the shape of a disc. The disc has a radius of more than 15,000 parsecs. This means that light takes more than 100,000 years to travel across the diameter of the galactic disc. At the centre of the disc, there is a distinct bulge having a radius of about 5 kiloparsecs. The disc is surrounded by a big halo. Globular clusters consisting of hundreds of thousands of stars are important constituents of the halo

The rotation of our galaxy, which causes the revolution of the Sun and other stars around its centre, was discovered about 1927 by the astronomers Bertil Lindblad of Sweden and Jan Oort of Holland from a study of motions of the nearby stars relative to the Sun. The earlier observations had indicated that while, roughly, one-half of the stars with velocities less than 20 or 30 km per sec was heading towards the constellation Scutum, the other half appeared to move in the opposite direction, towards the constellation Orion (Fig. 3). There were some stars which moved swiftly, with velocities up to 130 km per sec relative to the Sun—five times faster than the others—and almost perpendicular to the direction in which the other stars streamed. Lindblad proposed that such a configuration was due to the fact that the Milky Way rotates about a region in the direction of Sagittarius which is close to Scutum causing the majority of stars to move in circular orbits. As seen from the solar system, nearly one-half of the stars moves inwards, towards the centre of rotation; the other half moves outwards, away from the rotation centres. The "high velocity" stars, actually, are laggards; they merely appear to move fast. They are indeed being overtaken by the stars in the streams. They move in highly elliptical orbits that take them close to the galactic centre.

How do the speeds of the stars change as we go outward from the centre of the galaxy? The velocity of a star with respect to the Sun may be resolved into two parts: the radial velocity along the line of sight and the tangential velocity perpendicular to the line of sight. The former is obtained from the Doppler shift of the lines in the spectrum of the star and the latter from the angular displacement of the star in the plane of the sky and the parallax of the star. Oort showed mathematically that if stars moved in circular, coplaner orbits around the galactic centre, the relationships between these velocities and the position of the star could be expressed by simple trigonometric formulae. Comparing the observed velocities for various positions of the stars with the velocities given by these formulae, Oort deduced that the Sun and other stars are revolving around the galactic centre as planets revolve around the Sun. The stars closer to the galactic centre take less time to complete one orbit than those away from the galactic centre.

The period of revolution of the Sun about the galactic centre, called a cosmic year is about 240 million years. Its orbital velocity is also deduced from the motions of the system of globular clusters in our galaxy and the system of nearer external galaxies. According to present estimates, the Sun is moving towards the galactic longitude $l = 90°$ in the direction of Cygnus constellation with a speed of about 220 km per sec (or about 800,000 km per hour).

Observations of the motions of the stars give us direct information about the rotation of the galaxy in the neighbourhood of the Sun up to about 1000 or 1500 parsecs. Between the stars, however, the matter in the form of gas and dust produces a kind of fog which makes it difficult for us to see the distant stars. But we can find the galactic rotation in the more distant parts of the galaxy by studying the motion of the interstellar gas.

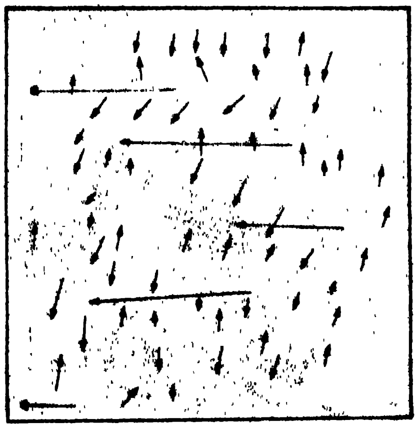


Fig. 3. The motion of the stars that are closer to the Sun was studied in detail by the Dutch astronomer Jacobus Kapteyn who noticed that stars do not move at random. Actually, two star streams are observed. Roughly, one-half of the stars moves towards the constellation Scutum and the other half towards the constellation Orion. (Both the constellations are parts of the band of diffuse light called the Milky Way.) Some of the stars, known as the "high velocity" stars, because they appear to move five times faster than the stream stars appear to move perpendicular to the stream stars

How is this done? The interstellar neutral hydrogen emits radiation in the region of radio waves at a wavelength of 21 cm. The motion of the gas results in producing Doppler shift of this line. From a study of the intensity of the radio spectrum in the region of 21 cm at various galactic longitudes, the distribution and motion of the interstellar gas in various parts of the galaxy are deduced.

By combining both the optical and the radio data, we obtain the velocity as a function of the distance from the galactic centre. This is known as the rotation curve. Fig.4 shows the typical rotation curve of a disk galaxy. The velocity increases linearly with distance from the centre in the innermost parts of the galaxy; it varies inversely as the square root of the distance from the centre in the outermost parts. And there is an intermediate flat section corresponding to a transition between these two regions.

The rotation curve of a galaxy gives valuable insight into the distribution of mass within the galaxy. Every bit of mass exerts gravitational force on other masses producing acceleration. And the motion of mass depends upon how the mass is distributed.

We may consider two extreme cases of mass distribution: (1) a spherical galaxy with a uniform density throughout, and (2) a point mass galaxy in which almost the entire mass is concentrated at the centre. From the Newton's law of gravitation it would then follow that, in the former case, the galaxy would rotate like a rigid body, the angular velocity being the same at all parts of the galaxy and the orbital velocity of a star increasing linearly with the distance from the galaxy's centre. In the latter case, the motion of the stars would be like that of planets in the solar system: the square of the angular velocity would be inversely proportional to the cube of the dis-

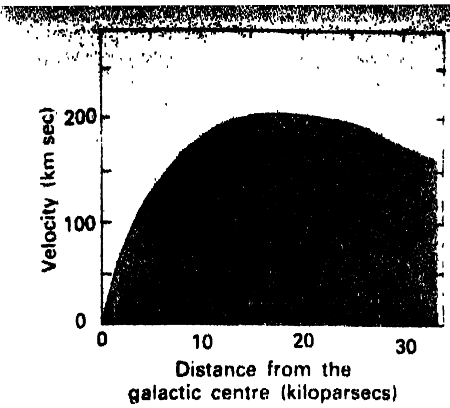


Fig. 4. The rotation curve of the disc galaxy M 101

Annual Review of Astronomy and Astrophysics

tance from the centre. Also the orbital velocity would be inversely proportional to the square root of the distance from the centre.

It therefore follows from the rotation curve that, in the innermost parts of the disk galaxy, the mass distribution is homogeneous, while the outermost parts contain little mass. An intermediate flat section, wherein the velocity does not change with distance, implies that the mass of the galaxy increases linearly with the distance from the centre. Recent observations of our galaxy and other disk galaxies indicate that the flat section continues over a vast region implying that the galaxies are surrounded by massive halos. The mass of our galaxy is estimated to be over 6×10^{11} times the mass of the Sun; the mass of the Sun being 2×10^{33} gms. The nature of much of the material forming the halo is, at present, a great puzzle in astrophysics.

A study of the physical properties of our stars shows that they differ in age. The Sun's age is about five billion years. In 1944, Walter Baade classified stars into Population I and Population II, the former consisting of younger and the latter of older stars. After more detailed classifications were made, it was found that the kinematic properties of the stars were correlated with their age.

Not all the stars move in circular orbits. Those deviating from circular orbits are said to have peculiar velocities. The younger stars lie closer to the galactic plane and have smaller peculiar velocities, while the older stars are also found at greater distances from the galactic plane and have larger velocity dispersions.

A detailed study of the distribution of matter in the galactic disk shows that our galaxy has a spiral structure with trailing arms. In 1951, W. W. Morgan and his associates at Yerkes Observatory gave the first proof of it from optical studies of the distribution of gas clouds and young clusters which populate its spiral arms. Soon after this, the radio studies of the 21-cm line of neutral atomic hydrogen showed that the spiral structure is closely wound. In 1964, C. C. Lin proposed that in a rotating flat star system minor density fluctuations may produce perturbations in the gravity field which would distribute the interstellar matter in the regions where the spiral arms are and where young stars are formed fro matter.

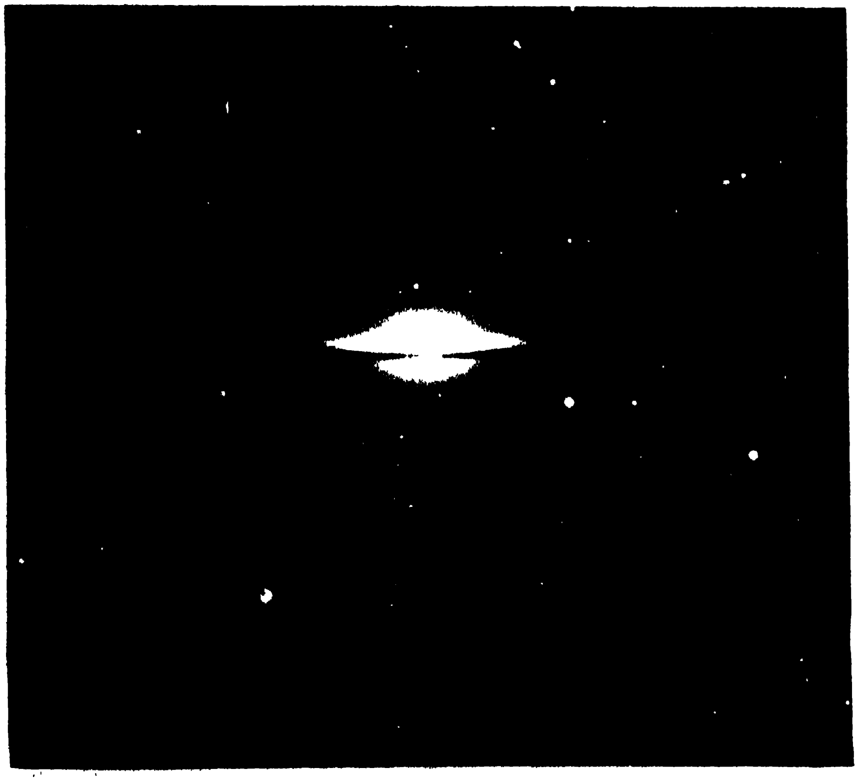


Fig. 6. NGC 4594—the "Sombrero Nebula"—edge-on view of a spiral galaxy

Indian Institute of Astrophysics

The external galaxies

Our galaxy is one among billio galaxies that populate the observa universe. How are the stars movin other galaxies? Observations indic that galactic rotations are clo related with their shapes. There two main types of galaxies—the El ticals and the Spirals. Ours is a dis shaped spiral galaxy. A third typ known as the Irregulars, constitut not more than five per cent of all galaxies. The ellipticals (Fig. 5) con tain little or no gas, while the spira

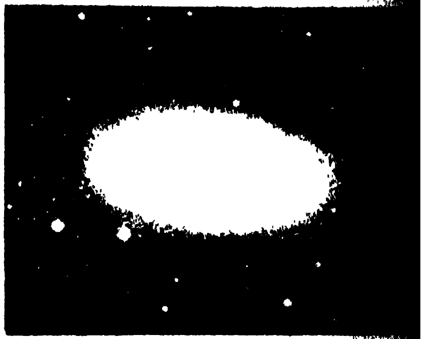


Fig. 5. An elliptical galaxy, NGC 205. Th galaxy is the larger of the two compani of the Andromeda galaxy

Hale Observatories

contain a significant amount of gas. rich clusters of galaxies (see the bo tom photo on p. 20 of last month SCIENCE TODAY), ellipticals abundant.

If we are to observe the spectra spiral galaxies, especially when galaxies are seen edgewise (Fig. we find that the lines in the spectr are tilted if the slit of the spectrogr is placed along the major axis of image. What does this indicate? Co sider a rotating disk galaxy edgewise (Fig. 7). The part A is rece ing from the observer and the part approaching him, while part C mo perpendicular to the line of sight; the spectrum of such a galaxy, obtained with the slit of the spe trograph along the major axis of image, the spectral line arising from would be shifted towards the lon wavelength side, that arising from towards the shorter wavelength si and that arising from C would show any shift in wavelength. Th the spectral line of the galaxy wo have a tilted appearance. No til observed if the slit is at right angle the major axis. No tilt is also obser if the galaxy is seen face-on (Fig. These results provide evidence the external spiral galaxies rot around axes that pass through th centres and are perpendicular to planes of the disks.

Motions in an elliptical galaxy different from those in the disks ral galaxies. While in the case of rals, the stars show strong preference for near-circular motions in e same sense; in the elliptical galax-s, the predominant stellar motions re at random. The motion of stars in e elliptical galaxies has been likened the flights of hunting sea birds. ome diving and others swooping pward while the others circle around em.

Elliptical galaxies have smaller gular momenta than the spirals. e angular momentum of a spiral laxy is roughly proportional to the uare of its mass.

e origin

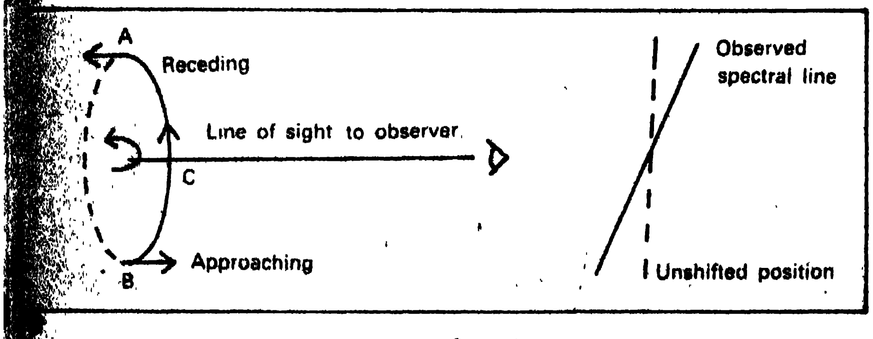
The rotation of galaxies is inti-ately connected with the processes which the galaxies formed and volved. It therefore puts useful con-raints on the theories of their origin. nce the angular momentum of an olated system is conserved, the ngular momentum now associated ith the galaxies was also existing in e protogalaxies (precursors of laxies) from which the present alaxies evolved. Observations indi-te that stars form from gas (see SCI-NCE TODAY, April 1981, p. 35). In rtain objects such as the Orion bula we can actually see the gas that being converted into stars and a rge number of recently formed ars. We therefore infer that pro-galaxies were large clouds of gas t possessed angular momenta.

The protogalaxies may have rived some angular momentum om the turbulence in the primitive s as suggested by von Weizsacker. more likely possibility is the tidal eraction with neighbouring pro-galaxies as envisaged by F. Hoyle. study of the motions of galaxies icates that they are receding from ch other with speeds that are ectly proportional to their sep-ation. Therefore, the galaxies were uch closer to one another in the past an they are now. They were also nsiderably larger, since their sizes ve been later reduced by gravi-ional contraction. Just as the Moon ses tides from the oceans of the rth, the protogalaxies must have sed violent tides from one another. This would have led to the acquisition of rotation. The amount of rotation a protogalaxy possessed was perhaps responsible for its subsequent collapse due to gravitational contraction into an elliptical or a flattened disk galaxy.

We get useful clues about the evolution of our galaxy from a study of the distribution and motions of its stars of various ages. As indicated earlier, the galaxy consists of subsystems. Their ages increase with their distance from the galactic disk; the older stars populating the halo and the younger ones lying close to the galactic plans. The conventional hypothesis has it that our galaxy collapsed from a huge, slowly rotating cloud with dimensions of the order of 100 kiloparsecs to a disk in time scale of the order of a billion years. The Population II stars formed during the collapse before the disk was formed while the Population I stars formed after the formation of the disk. Other spiral galaxies may have also formed in the same way.

It can be seen that rotation has played an important role in the evolution of our galaxy. The principle of conservation of angular momentum implies that as the gas cloud constituting the protogalaxy collapsed to a disk, the material went on spinning faster and faster. The stars that formed from the rapidly rotating disk have nearly circular and coplaner orbits, while the older stars which formed during the collapse are distributed throughout the volume in which they formed and move in orbits of greater eccentricity. This picture of the evolution of the galaxy accounts for the observed correlations between the orbits of the stars and their ages.

Why is it that the elliptical galaxies did not collapse to a disk? One reason for this could be that the gaseous cloud from which they originated was rapidly converted into stars so that the gas from which they originated was soon exhausted and could not form a rotating disk. Don't the elliptical galaxies contain old stars and little or no gas? Since an elliptical galaxy has a smaller angular momentum about the axis of rotation than a spiral galaxy, it appears that rotation hinders star formation.



g. 7. Tilt of a spectral line due to rotation of a galaxy

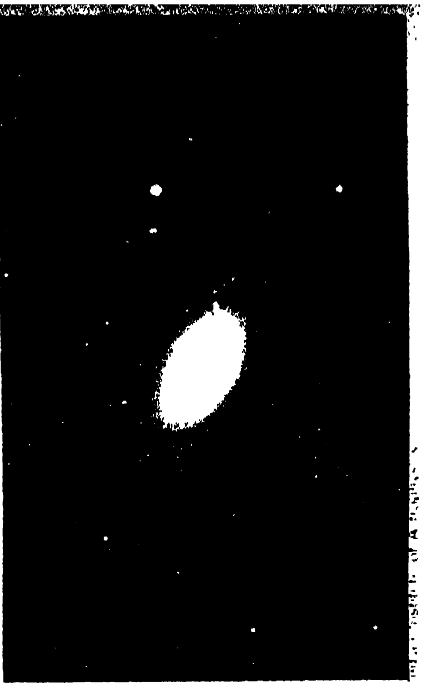


Fig. 8. NGC 3031—a bright spiral nebula with a bright nucleus. The spiral arms are very faint. Face-on view of a spiral galaxy

The angular momentum of a galaxy remains constant during its evolution only if it remains isolated. An encounter between two galaxies would alter their spin. Photographs of galaxies show a number of galaxies in the process of merging. Theoretical studies indicate that a merger of two disk galaxies can produce a galaxy of elliptical shape. The spin of the elliptical galaxy thus formed will depend on the spin of its progenitors as well as the initial orbit of the pair.

Thus the rotation of the galaxies bears valuable imprints of the processes through which the galaxies formed and evolved.

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Recommends reading: **1.** B. Bok and P. Bok, *The Milky Way*, Harvard University Press, 1981; **2.** Harlow Shapely, *Galaxies*, Harvard University Press, 1972; **3.** A. E. Roy and D. Clarke, *Astronomy: Structure of the Universe*, Adam Hilger Limited, Bristol, 1977; **4.** R. J. Tayler, *Galaxies: Structure and Evolution*, Wykeham Publications, London, 1978; **5.** Joseph Silk, *The Big Bang*, W. H. Freeman and Company, San Francisco, 1980.

Is The Universe Rotating?

J. V. Narlikar

There are faint indications that it is, but more sensitive probes are necessary before we can decide on the question

IT is said that man made a significant advance in surface transport when he discovered the wheel. From the wheels of a bullock cart to the motors which drive our present technology, we see numerous practical uses of rotation. But, apart from these man-made discoveries, rotation forms an intrinsic and vital part of natural phenomena. From the spinning sub-atomic particles to planets and stars we have a wide range of examples of rotation. Indeed, astronomers tell us that even such large systems as galaxies containing a hundred thousand million stars also rotate. And these findings have led to the speculation about the largest system that can be conceived: the Universe. Is the Universe itself rotating?

Before we seek an answer to this question, let us pause and ask what does the question itself mean?

Does the Earth rotate?

Whenever we talk of a rotating body we have a background in mind, against which the rotation is measured. Take the Earth, for example. The ancient Greeks believed that the Earth is fixed and that the rising and setting of stars is explained by the fact that the celestial sphere containing the stars itself revolves round the North-South axis. Of course, a modern schoolboy is taught that it is the Earth that rotates about its North-South axis and completes one rotation in 24 hours against the background of *fixed* stars. Which of the two interpretations is right? Indeed if the argument is based simply on what is considered fixed and what is considered rotating, the issue will never be resolved. The ancient Greek would continue to argue just as vehemently that the Earth is fixed as the modern astronomer would that it is the stars that are fixed.

Fortunately there is a criterion for resolving the issue—a criterion that tells us also about how to measure the rotation of the Universe. For, remember: the Universe by definition includes everything. There is no "outside background" against which we could measure its rotation. Let us see how therefore we can attach a meaning to the phrase "rotating Universe".

The Foucault pendulum

We return to the controversy of the fixed stars and rotating Earth, and consider an experiment first designed by the French physicist Leon Foucault in 1851. The experiment involves a simple pendulum which is free to oscillate in any vertical plane. Now, the bob of a pendulum—if it is pulled to a above its lowest position released from rest—would con to swing to and fro until air fric brings it to a halt. This to and motion is caused by the Earth's gra ity which acts in a vertical pla Because of this force the bob expected to move in the verti plane in which it was released fr rest. In reality the bob of the pe dulum does not quite do that! If let it swing for a long enough time (minimising air friction through le ting it swing in vacuum, say) we fi that the vertical plane in which swings itself rotates slowly from Ea to West (Fig. 1).

The reason for this apparently od behaviour of the Foucault pendulu is not difficult to trace if we go ba to the fundamentals of dynamics— the laws of motion propounded b Isaac Newton in 1686-87. Newton laws relate the acceleration (that the rate of change of velocity) of moving body to the forces acting o the body. However, as Newton him self realised, these laws do not wor in arbitrary frames of referenc Newton postulated the so-calle "absolute space" as *the* frame o reference in which the motion of th body was to be described, if his law were to work. If we decide to us another frame of reference we ma have to modify the laws of motion. I particular, if we elect to use a fram of reference *rotating* relative to th absolute space, we would have to ad fictitious forces, called the *iner* *tial forces* to the already existin external forces on the body.

If we are travelling in a fast car an if the car makes a sudden turn we ar thrown in the direction opposite t that of the turn. What invisible for is responsible for throwing us ou ward? It is the inertial force whic

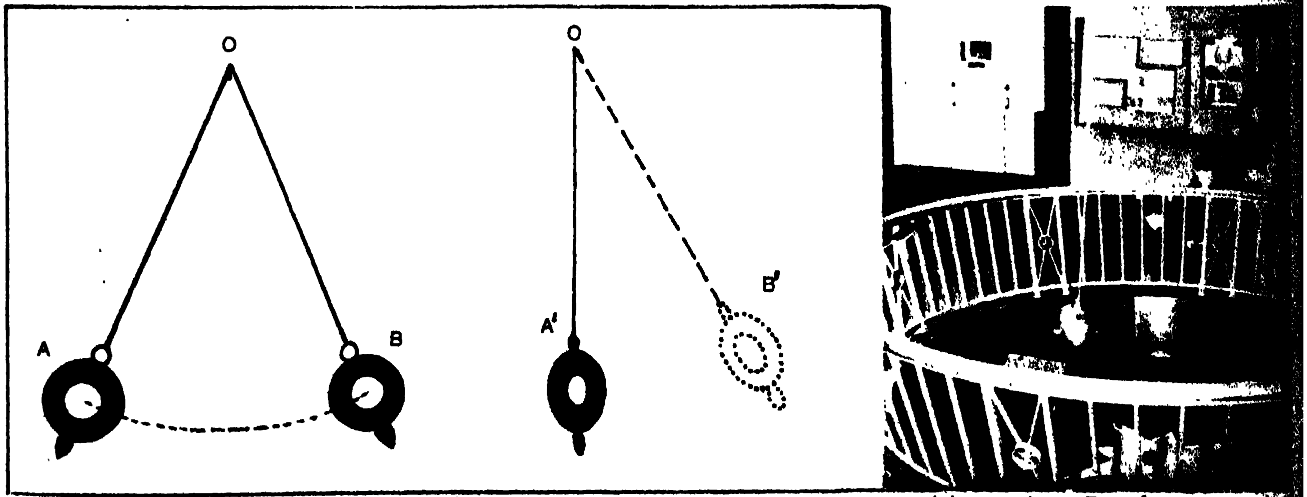

Fig. 1 The Foucault pendulum oscillating in the plane OAB (left). Because of the Earth's rotation, the plane of the pendulum gradually goes round the vertical axis through O and the plane of oscillation rotates to OA'B' (centre). A working model of the Foucault pendulam (right) The original pe dulum, 60 m long. was suspended from th roof of the Pantheon in Paris

ises because our frame of reference hat is that of the car) is accelerated lative to the absolute space.

e ancient controversy resolved

The odd behaviour of the Foucault endulum is explained if we assume hat its frame of reference (that is, hat fixed on the Earth) is rotating lative to absolute space. The inerl forces arising from the use of this otating frame of reference make the ane of oscillation slowly rotate om East to West. The rate of rotaon depends on the latitude of the lace, it being zero at the equator and aximum at the poles. And from hese measurements we deduce that he Earth as a whole is rotating about s polar axis from West to East at the te of nearly one rotation in 24 ours. This rotation is relative to ewton's absolute space.

So, if the absolute space is the ackground against which rotation is o be measured then the ancient Greeks were wrong: the Earth *is* otating and the distant stars are at est.

Well, almost. Careful astronomcal observations over several ecades have shown that the stars are ot exactly at rest relative to the bsolute space, either. The stars in our Galaxy are slowly changing their irections in such a way as to imply hat the Galaxy as a unit is rotating bout an axis. The rate of rotation is uite slow—one rotation taking about 00 million years!

However, we now have a criterion o decide whether the Universe is otating or not. The method is to look ay beyond the stars of our Galaxy, o the vast world of galaxies themelves, and to see if the background of remote galaxies is at rest relative o the absolute space of Newton. If it s, then the Universe is non-rotating.

e Expanding Universe

This world of galaxies was disovered by astronomers in the 1920's nd towards the end of that decade ame Edwin Hubble's remarkable scovery of nebular redshift. In simle terms, Hubble's discovery plied that the remote galaxies are l moving away from us. This motion s radially away from us—it is not of e transverse type that would imply rotation of the Universe.

During the early 1920's, G. A. riedmann had already constructed mple mathematical models of the o-called "Expanding Universe" sed on Einstein's general theory of lativity. These models turned out o be successful in describing Huble's observations, and essentially id the foundations on which modrn cosmology is based.

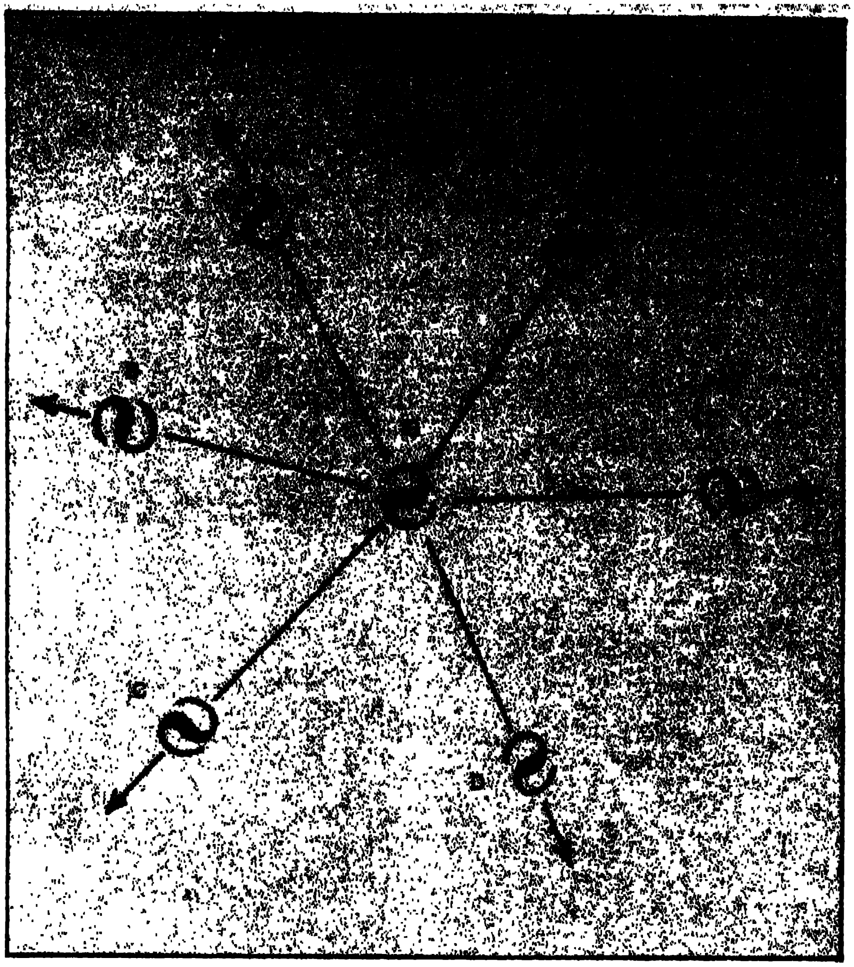

Fig. 2. The distant galaxies A, B,.......F as seen from our galaxy G are moving radially away. A rotating universe would require systematic transverse motions round a preferred direction. Such transverse motions have not been detected

The Friedmann models describe a non-rotating Universe. In the Friedmann Universe the background of distant galaxies is at rest relative to the absolute space. Thus, apparently, we have a satisfactory agreement between theory and observations. Observations do not seem to show any rotation of the background of distant galaxies and the theory is able to account for them with the help of a mathematical model. (Fig. 2).

Mach's principle

The observation that the remote parts of the Universe are non-rotating relative to the absolute space is something of a mystery. The philosopher-scientist Ernst Mach (1836-1916) turned the mystery into something more tangible. Mach argued that all along Newton's absolute space has been no more than an abstract and *ad hoc* concept, and that the correct way of handling the laws of motion is to state them against the background of remote objects. In other words, it is the remote parts of the Universe which determine the local absolute space. Mach further argued that his reasoning also implied that inertia of a body, which is measured by its mass, is determined by the remote parts of the Universe. These ideas, which were never quantified by Mach, are known as Mach's principle.

From our discussion so far it is clear that a non-rotating Universe forms the basis of Mach's principle. And, since the simplest models of the Universe turned out to be non-rotating, this result led Einstein to hope that his general theory of relativity incorporated Mach's principle, albeit in an indirect way.

This hope of Einstein's was belied ironically enough on his 70th birthday! For, in 1949, in a scientific volume dedicated to him on this birthday, among the numerous articles by distinguished scientists was one by Kurt Gödel which explicitly showed that general relativity did not incorporate Mach's principle. (It was the same Gödel who in 1931 had proved the remarkable result that the system of postulates in arithmetic is incomplete. This result, known as Gödel's theorem, is of fundamental significance to foundations of mathematics.)

Gödel's Universe

What Gödel did was to produce a model of a rotating Universe out of Einstein's equations of general relativity. As a model of the actual Universe, the Gödel Universe is hardly satisfactory. It does not show Hubble's redshift phenomenon. What is more, it has 'closed time-like lines' which means that it is possible for a class of observers to meet themselves in the past! Further, it makes use of the λ-term, a cosmic force of repulsion first introduced by Einstein but subsequently considered to be non-existent by most cosmologists including Einstein.

Nevertheless Gödel's model was a mathematical counter-example which opened the way for many more to come. Thus later workers were able to construct models of rotating universes free from the above defects of Gödel's model. And it is now clear that general relativity does not incorporate Mach's principle.

Does rotation prevent singularity?

Apart from Mach's principle, there is another aspect in which the rotating models have generated considerable excitement. The non-rotating models of Friedmann suffer from one defect. They have the Universe originating in a big bang. The big bang represents a singular epoch before which nothing (not even space and time) existed, an epoch at which the geometrical properties of space and time broke down and no physical description of any sort was possible. This singularity is worse than any mathematical or physical difficulty encountered in other branches of science before. Naturally, theoreticians wanted to know whether such a situation could be avoided.

In 1955, the Indian relativist, Amal Kumar Raychaudhuri, derived a result, now well known as the Raychaudhuri equation. Raychaudhuri showed that if the Universe has rotation, then its dynamical properties are different from those of the Friedmann universes. In particular, the additional terms introduced by rotation seem to help in preventing the singularity. Unfortunately, Raychaudhuri's equation did not explicitly say whether singularity *is* prevented. Indeed, as Raychaudhuri pointed out, a rotating Universe also has another property called 'shear' and the shear terms *help* the incidence of singularity. So the tantalising question remained: which of these two opposing trends would win out?

One way to decide this question was to construct explicit solutions of Einstein's equations with rotation and shear to show that the singularity is prevented. Otto Heckmann and Engelbert Schücking who strongly believed that rotation does prevent singularity (a belief generated by their working with Newtonian gravity) worked in this direction, but without success. Only in the late 1960's, with the work of Roger Penrose and Stephen Hawking, did it become clear that singularity is a salient feature of relativity — a feature which cannot be removed by such devices as rotation. With this result the main theoretical attraction of rotating models has gone.

Astronomical observations

Nevertheless we, as observers, can still ask this question: "Is the Universe rotating?" We have already seen how slowly galaxies can rotate. Can we not expect the Universe to rotate even more slowly—completing one rotation in, say, ten thousand million years? For, this is the characteristic time-scale to emerge from cosmological observations. A rotation rate so slow would be very difficult to measure directly; but can we detect its effect indirectly? I end this article with a discussion of two such effects.

An indirect consequence of rotation is anisotropy. The distribution of matter in the Universe is expected to show a dependence on direction with respect to the direction of rotation. Thus, differences with respect to direction should show up in the distribution of galaxies, radio sources, etc. Have such differences been found? At the time of writing there *are* a few such effects which show that the matter distribution in our local neighbourhood is not isotropic. For example, the Rubin-Ford effect tells us that the Hubble law relating the speed of recession of a galaxy to its distance from us is anisotropic. There is also some indication from the radio surveys that the counts of sources are not quite isotropic. However, such effects, even if conclusively established, do not *prove* that the Universe must rotate. These effects could also be explained by postulating local inhomogeneities like superclustering of galaxies.

Anisotropy has also been detected in the background radiation in microwaves which pervades the Universe the bulk of the effect is however due to the fact that the Earth is moving around the Sun, which itself is going around the Galaxy which in turn may have motions of its own relative to distant galaxies. After eliminating this source of anisotropy, a small effect still remains. This small anisotropy which has *not* been conclusively established today suggests that the Universe is rotating.

Finally, laser technology has opened up the promising prospect of measuring the Earth's rotation relative to the absolute space much more accurately than what is possible with a mechanical device like the Foucault pendulum. At the 9th International Conference on General Relativity and Gravitation held at Jena, M. P. Haugan, M. O. Scully and M. S. Zubairy from the Optical Sciences Centre of the University of Arizona presented an experimental scheme which is expected to achieve a sensitivity of one part in ten thousand million of the Earth's rotation rate. The scheme uses a device known as ring interferometer with an argon laser.

Such accurate laboratory experiments coupled with the much more sensitive probes of the remote parts of the Universe promised by the Space Telescope to be launched by NASA in 1983 will be needed before we can assert confidently whether the Universe is rotating or not.

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ROUND-UP OF RESEARCH

Early diagnosis and treatment of bleeding peptic ulcers

PEPTIC ulcer is a common medical problem all over the world. It occurs either in the stomach (gastric ulcer) or in the first part of the small intestine (duodenal ulcer). The latter is more common and predominantly affects men in the prime of life, between the ages of 25 and 45 years. Apart from causing much agony to the patient in the form of severe periodic attacks of pain in the upper abdomen and vomiting, it can also cause serious complications such as vomiting of blood or "haemetemesis". This happens when the ulcer burrows deep in the wall of the stomach or duodenum and damages one large artery or several small blood vessels. Bleeding in some ulcers stops spontaneously, but in others the continuous, profuse bleeding may threaten the very life of the patient.

When the patient comes to the hospital with haemetemesis for the first time and his previous history is not typical of peptic ulcer, the diagnosis of the cause of bleeding is not easy, as there are many causes of haemetemesis. Accurate diagnosis is, however, imperative as the treatment for each condition varies widely.

Though Barium meal X-ray examination of the stomach and duodenum has been available for a long time, its accuracy in pinpointing the cause of haemorrhage is limited (less than 50 per cent).

With the availability of fibreoptic endoscopes for examination of the gastrointestinal tract, the accurate diagnosis of the cause of haemetemesis has become possible in 98 per cent of patients. The fibreoptic endoscopes are flexible tubes which can be passed into the oesophagus, stomach and intestines of the patient without discomfort, after he has been mildly sedated and a local anaesthetic has been sprayed in his throat. The scopes contain a system of glass fibres and lenses and work on the principle of total internal reflection of light. This means that, in spite of the instrument traversing many natural bends and curves inside the body, it continues to transmit the image to the observing physician without interruption. With this endoscope, the ulcer and even the eroded blood vessels, inside the ulcer "crater" can be observed.

However, it is not adequate to diagnose a disease accurately. A bleeding ulcer has a high mortality rate, particularly in patients over 60 years of age, and urgent steps to stop bleeding are imperative. This is done either by operation or by coagulating the bleeding vessel by a laser beam (laser photocoagulation). The latter is not available in our country as yet. On the other hand, severely bleeding patients who are not in a good general condition pose a risk to anaesthesia and surgery. Thus, it is necessary to balance the risk of immediate operation vis-a-vis waiting for natural control of haemorrhage (clot formation over the ulcer).

How to resolve this dilemma is a challenge facing the endoscopists the world over. If it could be made possible for the doctor to predict which ulcers are likely to rebleed and which would not, it would be possible to separate these patients into two groups, those requiring immediate surgery and those who could be managed conservatively on blood replacements and drugs.

This is precisely what D. Storey, Bown and their colleagues studied at the St James' Hospital, London (*New England Journal of Medicine*, **305**, 915). Using a fibreoptic endoscope, they examined 292 patients of hematemesis within 24 hours of the start of bleeding. In 117 of them, peptic ulcers were diagnosed in which full examination of ulcer crater was possible. Of these, 87 were followed up over one week without administration of any specific therapy, and 34 showed "a visible vessel" in the ulcer crater, 13 had oozing (the former due to the ulcer damaging a large blood vessel and the later due to slight erosion of a large vessel or damage to small vessels) and 40 patients showed no active bleeding.

Nineteen out of 34 patients with a visible vessel re-bled within the next seven days and 17 of them were operated upon. Of the 13 patients with oozing from the ulcer, one showed re-bleeding and he was also operated upon. Those 40 patients who had not shown bleeding at the time of endoscopy, did not re-bleed during the course of observation and were not submitted to surgery. Thus, finding a visible vessel and oozing is very helpful in deciding which group of patients requires surgery and/or drugs.

In our series of endoscopic examinations also, the value of fibreoptic endoscopy, both in diagnosing the cause of gastrointestinal bleeding and planning their proper treatment, has been demonstrated.

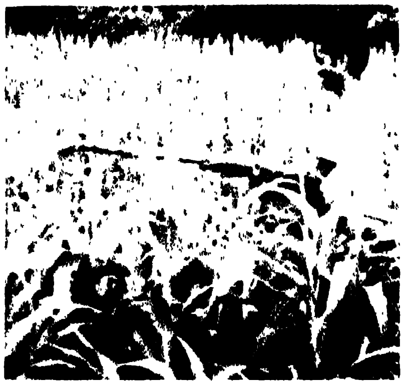
SUCHARITA A. NANIVADEKAR

Dr. Nanivadekar is Professor of Medicine and is in-charge (gastroenterology) at the Lokmanya Tilak Medical Hospital and College, Sion, Bombay.

Green revolution and the spread of malaria

ONE would wonder how an increase in rice production can bring about the spread of malaria in a country. That is what has indeed happened and is causing alarm in Central America and India, according to an article recently published (*Nature* **293**, 181) by G. Chapin and R. Wasserstrom from the Division of Sociomedical Sciences, School of Public Health, Columbia University, New York, USA.

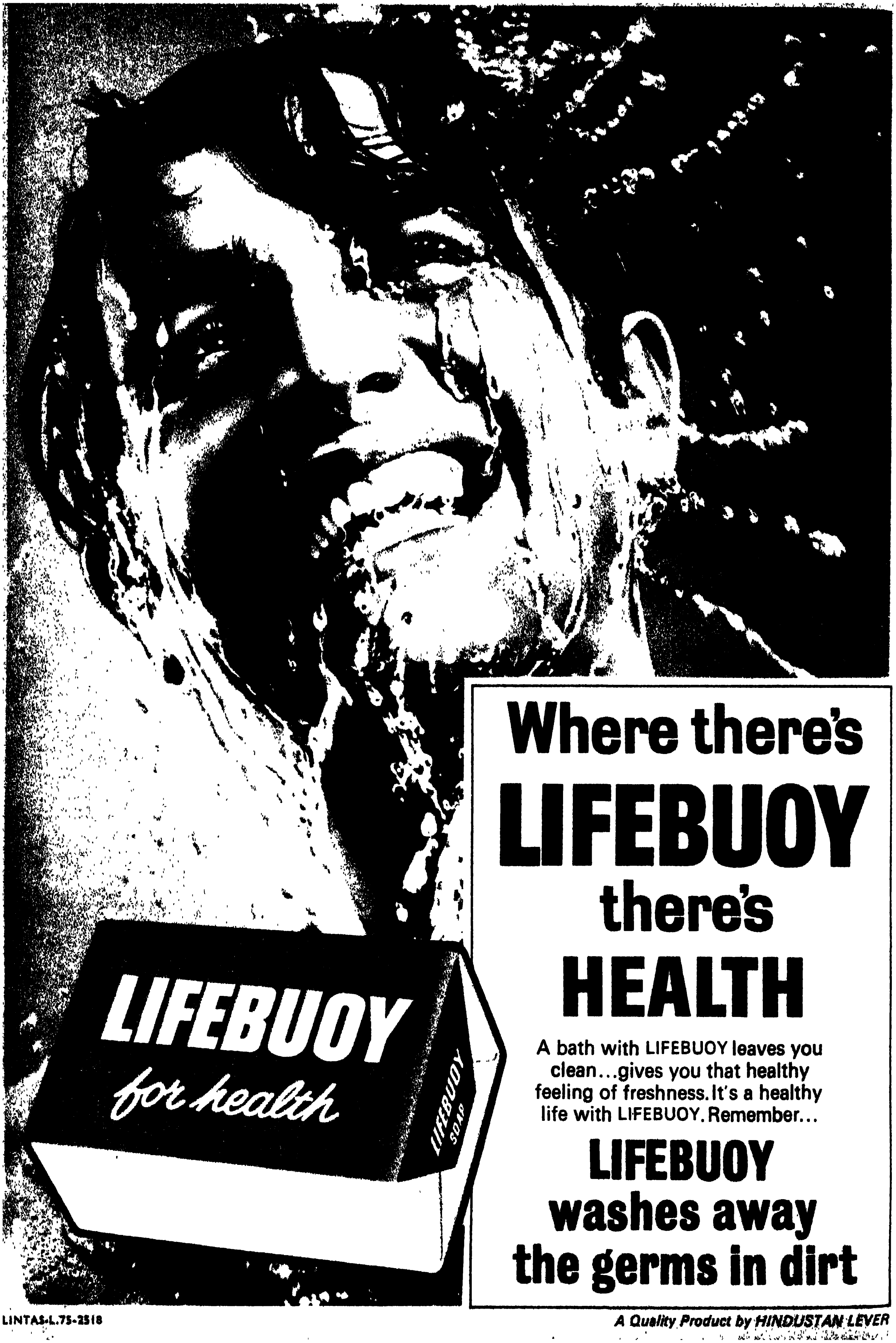
Malaria is transmitted from man to man by the *Anopheles* mosquito. The adult female mosquito picks up the sexual forms of one of the four malaria parasites of the genus *Plasmodium* that infects man (SCIENCE TODAY, December 1980). The whole process of development of the parasite in the mosquito takes anywhere from 10 to 21 days, depending on the environmental conditions.



Pesticides—the culprit?

Theoretically, to arrest malaria, we must intervene in the life cycle of the parasite by either preventing multiplication of the mosquito vector or effectively killing them with insecticides or the parasite with drugs. Some of the early methods used to prevent breeding of mosquitoes involved the draining of swamps, and the emptying, covering or oiling of pools of standing water. It was during the Second War, that cheap and effective chemical pesticides, such as DDT and dieldrin, came into existence. These are persistent at the site of application for months and thus are ideally suited for killing *Anopheles* mosquitoes. However, the widespread use of these drugs brought about the development of resistance by the insects to these chemicals.

The resistance phenomenon is due to a genetically endowed ability of a subpopulation of insects to tolerate certain doses of an insecticide, which would be lethal to the majority of the population. During persistent exposure to the insecticide, the susceptible population is gradually eliminated and the proportion of resistant insects increases very rapidly. Eventually, the insecticidal pressure makes most of the population of insects



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In India there were a hundred million cases of malaria in 1952 with over 0.8 million deaths occurring due to the disease. The combined effects of chemotherapy and DDT spray resulted in a dramatic reduction of the incidence of malaria to a bare 100,000 by the year 1965. Such an effect was also seen in several other countries where malaria was a problem. However, in 1953, it was realised that a proportion of *Anopheles* mosquitoes were exhibiting resistance to the insecticides.

Since 1961 there has been a resurgence of malaria in these countries. By 1971, India registered over six million cases of malaria with few deaths due to the disease. Similar resurgence was also seen in Sri Lanka and Central America. The prime reason for the resurgence, according to the authors, was development of insect resistance to conventional insecticides such as DDT and dieldrin. The emergence of resistance, state the authors, is hastened by the extensive use of insecticides in another area.

At this time, there was an expansion of agricultural production in several regions of the world, particularly in areas recently cleared of malaria. Since 1960, the more affluent Indians owning considerable segments of the croplands, began to raise cotton, rice and tobacco. Insecticides ranging from chlorinated hydrocarbons, organophosphates and even carbamates were used heavily to ward off the pests. A similar phenomenon occurred in other parts of Asia and Central America. They increased fumigation of their fields nearly six fold each season and thus contaminated the local ecosystem with these pesticides. Consequently, mosquitoes of both *Anopheles* and *Aedes* (vector of certain viral infections such as dengue fever and yellow fever) have become resistant to the chemicals.

The authors attempted to establish a link between the resurgence of malaria in most developing countries, particularly of Asia and Latin America, and the increasing use of pesticides for high-yielding forms of agricultural production. They even state that resistance began to occur with the introduction of green revolution technology, dealing particularly with the use of high-yielding varieties of rice. However, the authors also state that several factors such as complaisance of the administrators that the malaria problem was licked, poor surveillance, inadequate finances, insufficient knowledge on the epidemiology of malaria are also responsible for malaria resurgence. In a lighter vein, some say that the malaria eradication programmes eradicated malariologists leaving the *Plasmodium* intact. Nevertheless, the authors justifiably conclude with an implied plea to the international agencies such as World Health Organisation and the Food and Agriculture Organisation that they should urge their member countries to employ integrated pest management systems that would not interfere with the malaria eradication programme, and also teach the farmers to make safer and efficient use of pesticides. Such an integrated approach was indeed developed in the United States largely due to the alarming increase in the residues of a variety of pesticides in the veterinary and the human foods, consequent to the more frequent application of these chemicals by the farmers in their enthusiasm to get higher yields of crops.

The authors also appeal to the U N agencies not to be influenced by the pesticide manufacturers but be guided by the perils of the unlimited use of the chemicals and advocate an integrated system of pest management on important agricultural crops of the countries. The health sectors of developing countries should take note of the invaluable suggestions of these authors since the vector control in their countries will continue to depend heavily on the use of pesticides for several years to come.

D. SUBRAHMANYAM

Dr Subrahmanyam is director of a multinational industrial research centre in Bombay His main research interests are in the immunology of communicable diseases such as malaria, filariasis and tuberculosis.

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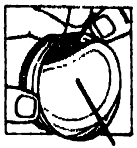

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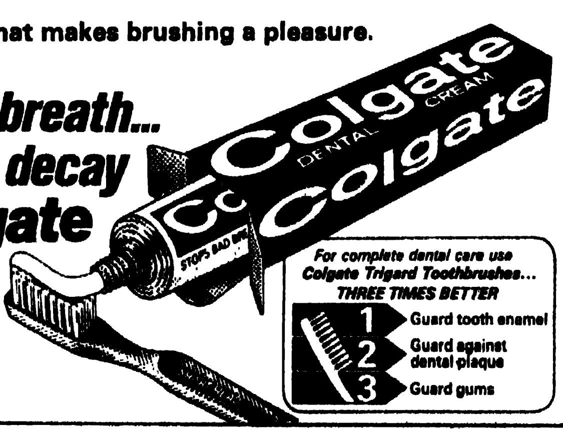

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THE NOBEL PRIZES, 1981

Physiology or medicine

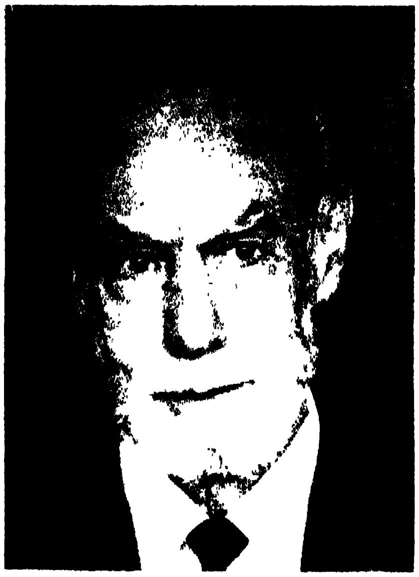
THE Nobel Prize for physiology or medicine this year was awarded to three neurobiologists—Roger W. Sperry, David H. Hubel and Torsten N. Wiesel—for their pioneering studies on the functional organisation of the brain.

Sperry, who receives half the prize, is a professor of psychobiology at the Division of Biology, California Institute of Technology. Sperry did his graduate work at the University of Chicago, and later, after spending some time at the Yerkes Laboratory with Karl Lashley, moved to the California Institute of Technology in the early fifties. He continued his work in three distinct areas—developmental neurobiology, experimental psychology, and investigations into the specialisation of the two halves of the brain on human subjects who had undergone split-brain surgery for epilepsy. Indeed, his contributions to all these areas have been so profound and so fundamental that upon hearing the news of the award his colleagues and students wondered as to what aspects of his work was being rewarded.

All organisms display a distinct bilateral symmetry. The plane of symmetry, passing through the midline and dividing the body into left and right halves, extends right into the brain. This is particularly conspicuous in the mammalian brain, where even a casual glance reveals the division of the cerebral hemisphere (the most prominent part of the brain) into two, left and right, halves with a deep groove extending around its circumference. Of course, the two halves are not entirely unconnected; they are joined together by a bundle of nerves.

Sperry and R. E. Myers carried out experiments on animals with the two halves of the brains surgically disconnected. They demonstrated a certain degree of specialisation for each half and further observed that the information received by one half could not get transferred to the other half.

The crucial evidence in support of the conclusions derived by Sperry and his group from experimentations on the animals, however, has to await the availability of human subjects who had undergone such split-brain surgery to control or minimise epileptic seizures. The studies cited in the Nobel award began in the early sixties, when Joseph E. Bogen suggested split-brain surgery for patients suffering from severe epilepsy. Sperry carried out a series of behavioural tests on such subjects using a variety of stimuli based on sight, sound and touch. The results were startling. Although they supported his conclusions derived from animal experiments, they were in sharp contrast with earlier human work, presumably due to ambiguity in the tests. He demonstrated that the left hemisphere specialises in analytical abilities such as logical thought process, speech, language, and writing. The mute or dumb right brain, earlier regarded as subservient to the more aggressive left half on account of its supposed inability to process verbal communication, specialises in emotions, spatial relations, appreciation of arts and music and indeed looks at the world outside in a holistic perspective. To give an illustration of the kind of tests Sperry carried out, a blind-folded subject is asked to pick up an object from an assorted set—consisting, say, of a pencil, a comb, a cigarette, and a bunch of keys, with his left hand. The patient knows from the 'feel' but cannot communicate verbally as to what the object is, since this perception from the left hand through touch goes to the 'mute' right brain. However, if the subject is permitted to use his right hand to get a 'feel' of the object or allowed to jingle out an object (assuming it is a keybunch giving out sound) he can then readily say what the object is.



Sperry

Although the Nobel citation refers only to the work on split-brain human subjects, any tribute to Sperry will remain incomplete if one does not mention his fundamental contribution in developmental neurobiology. Working on the regeneration of optic nerves in amphibians and fish, he probed into the question as to what guides the growing axons (the nerve fibre or a process of a neuron) to reach their right destination in the brain. His theory of chemospecificity, although yet to be substantiated, continues to play a provocative role in stimulating experimental investigations.

The other half of the prize has been shared by Hubel and Wiesel, both of the Harvard Medical School, for their work on the organisation of the visual system. Hubel is George Packer Berry Professor of neurobiology. A Canadian by birth, he received his MD degree at the McGill University, Montreal, followed by studies on clinical neurology at the Montreal Neurological Institute. He migrated to the USA in 1954, and, after a brief association with the Johns Hopkins School of Medicine and the Walter Reed Army Institute of Research, he moved to the Harvard Medical School in 1960. Wiesel, Swedish by birth, obtained his MD from the Karolinska Institute, Stockholm. He joined the Harvard Medical School in 1959, and is presently Robert Winthrop Professor and chairman of the Department of Neurobiology there.

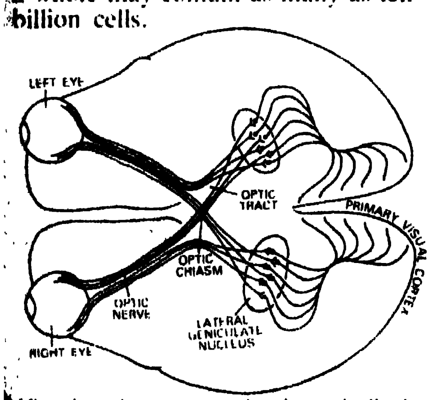
The peripheral location of the eye with its functional components—retinal cells and the optic nerve—is readily accessible, and the ease with which it can be subjected to a wide variety of light stimuli have made the visual system a versatile model for neurobiological investigations. Most neurophysiological studies until the early fifties were confined to the 'fish level' of organisation. A general principle that emerged from these investigations was that cells respond to contrast at the edges of a high bar or to onset and cessation of the stimuli. Further, symmetrical receptor fields, comprising light spots of definite sizes, can be assigned to ganglion cells in the retina. Studies on

Hubel

Wiesel

frogs suggested a rudimentary level of integration at the retinal level, which could enable the animal to distinguish shapes and forms and respond optimally to moving objects. It was indeed the failure to find such elements of integration in the retina of cats and other higher animals that prompted Hubel and Wiesel to explore the higher levels of organisation in the visual pathway.

The visual pathways in mammals are distinctly more complex than those in amphibians and fish. The axons of the retinal cells bundled together into the optic nerve make connections both in two lateral geniculate nuclei (a mass of sensory and sympathetic nerve cells located along the facial nerve) in the brain. Each geniculate receives inputs from both the eyes, dividing the composite visual field of the two eyes into left and right. (This is in contrast with the complete crossing over, that is, the left eye making connections only with the right half of the brain and vice versa in fish and amphibians.) Apparently, the geniculates function as a two-way station, segregating the inputs from the two eyes. Axons of the cells in the geniculates make contact with the primary visual cortex located in the back of the cerebral hemisphere. The cortex is a highly folded multilayered plate covering the whole cerebral hemisphere. It has about 100,000 cells per square millimetre of the surface area, and as a whole may contain as many as ten billion cells.



Visual pathways traced schematically in the human brain, seen here from below

As Hubel and Wiesel discovered, it is at the level of the primary cortex that the inputs from the geniculates are integrated to generate the elements necessary for the perception of form and movement of the objects. The methodology involved passing a microelectrode into the brain through a hole in the skull and recording the electrical signals from single cells in response to a variety of high stimulus spots, bars, etc, presented in the visual field. These studies were reported in a series of papers starting in 1959.

They demonstrated the presence of what they called "simple" cells which responded to a bar of light with specified orientation and in a particular position of the visual field. There are then the "complex" cells, which are not so fussy about the location of the stimuli, but respond optimally when a bar of light of specified orientation is swept over the visual field. More recently Hubel and his collaborators have provided an impressive set of evidences in support of the columnar organisation of cells in the visual cortex, using radioactive amino acids as tracers to define inter-neuronal connectivity.

U. N. SINGH

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Physics

THE 1981 Nobel Prize in physics has been awarded to the three scientists whose work on the development of electron and laser spectroscopies has been largely responsible for a great revolution taking place in the study of atomic and molecular systems. Kai Siegbahn, 63, of the Institute of Physics at Uppsala, Sweden, receives one-half of the prize for his pioneering work on the use of X-ray photoelectron spectroscopy (XPS) to investigate the nature of electron configurations in a wide variety of atomic systems, while Nicolaas Bloembergen, 61, of Harvard University, and Arthur Schawlow, 60, of Stanford University (both in the USA) share the other half of the prize for being instrumental in establishing non-linear optics and laser spectroscopy as the most versatile fields of research for precision measurements in quantum electronics, physics, chemistry and biology.

Siegbahn

As we know, the frontiers of science do not lie on a single simply connected surface. In the words of Victor Weisskopf, one has at least two kinds of frontiers: external and internal. The external frontier explores those realms of natural phenomena whose fundamental laws are still not understood by us at present, as in the case of the subnuclear world, or astrophysics. The internal frontier on the other hand mostly concerns with the world of atoms and molecules composed of negatively charged electrons and comparatively massive positively charged nuclei, with electric interaction between them. Although, the basic dominant law on which these systems operate is known on an elementary level, a tremendous variety of combinations and recombinations of atoms forming specific structures and superstructures gives rise to many [illegible] complex phenomena which, [illegible] unable to understand and explain. In this sense, the study of bonding of atoms to form specific molecules, molecules forming linear chains [illegible] macromolecules or two-dimensional membranes or three-dimensional crystals or liquids or plasmas, including the phenomenon in which some structures can reproduce themselves, forms the internal frontier of science. Any technique which can bring us a little nearer to an understanding of some of these phenomena is of great value in science, and this has been well recognised by the Nobel Committee. Of course, the great complexity and variety of these structures and forms of matter sometimes give them unique and very useful properties of technological importance.

Optical spectroscopy as a field of research is almost a century old. During the first thirty years of the twentieth century, it, in fact, led to the two crucial cornerstones of modern physics: the understanding of the atomic structure and the development of quantum mechanics. In an atom or a molecule, bound electrons move in definite orbits with discrete energy levels. An electron in any of the bound levels is not free to move out of the atom unless one supplies external energy equal to or more than the binding energy E_B of the level. Light of a given frequency is usually emitted whenever an electron in a bound excited orbit jumps to an unoccupied orbit of lower energy, giving rise to a spectral line. When the difference in energy between the orbitals is larger than optical photon frequencies, one, of course, gets a higher frequency photon in the ultraviolet or the X-ray region of the electromagnetic spectrum, instead of the usual light.

Bloembergen

Conversely, the absorption of light or X-ray raises the electron orbital from a lower energy to higher energy level. If sufficient excitation energy $h\nu$ is provided, one can excite an electron in a given level in an atom beyond its ionisation [illegible]hold or an electron in a mole[illegible]ond its dissociation level (level where a molecular bond between atoms breaks) so that the electron is no longer bound in the system, and it moves out with the kinetic energy (½) $mv^2 = h\nu - E_B$. These are the so-called photoelectrons, analysed in photoelectron spectroscopy to find the binding energy E_B of the level.

Albert Einstein indeed received the 1921 Nobel Prize for explaining the origin of the photoelectric effect in 1905. The second-order two-photon quantum process in which a system simultaneously absorbs a photon and emits another one, with the difference in their frequencies determined by the low-lying excited levels of the system, is the well-known Raman scattering. C. V. Raman received the physics Nobel Prize in 1930 for discovering this process in 1928. It is quite obvious that the methods of absorption, emission, photoelectron and Raman spectroscopies give rise to the most valuable information about the changes in the nature of the energy levels and atomic configurations of the atomic system forming specific structures and super structures.

Although it was known for a long time that the binding energy of atomic levels can be determined by measuring the kinetic energy (½) $mv^2 = h\nu - E_B$ of the photoelectrons excited by monoenergetic photons of energy $h\nu$, its use was limited due to lack of precision in measuring the velocity v of the ejected photon-electron. To obtain acceptable values of E_B, it is necessary to measure the kinetic energy with a precision comparable to other direct methods in

Schawlow

optical spectroscopy. It was Siegbahn who, with his co-workers at Uppsala, used his earlier experience in analysing electrons in β-ray nuclear spectroscopy to make the necessary technical development to initiate the use of electron spectroscopy for chemical analysis (ESCA). He used well collimated X-ray sources, in spite of their large linewidths, for exciting the photoelectrons in atoms, molecules as well as solids. Earlier, in 1924, his father Karl Manne Seigbahn had received the Nobel Prize in physics for his work on X-ray spectroscopy.

One of the problems of X-ray photoelectron spectroscopy for studying metals or other solids is the fact that a photoelectron emitted deep in the bulk loses a part of its energy to other electrons or ions before coming out of the sample for detection, thereby being unable to provide information on its original kinetic energy. In this sense, the method is inherently more sensitive to surface atoms. It can indeed easily detect extremely small amounts of contamination on surfaces. However, Siegbahn showed that because of the much narrower energy peak expected from those electrons which manage to escape without scattering inside the sample, it is also possible to study the bulk properties. This method has now been extended to the ultraviolet region also, giving rise to ultraviolet photon spectroscopy (UPS) which is much more accurate for the outer valence electrons in the sample. With the development of new powerful synchrotron excitation sources which give well collimated, intense monoenergetic photons in the optical to hard X-ray regions, photoelectron spectroscopy has now become one of the most important fields to study general atomic and molecular systems as well as surfaces.

The advent of tunable lasers as highly intense, monochromatic, and coherent optical sources during the last decade has not only revolutionised the traditional methods of absorption, emission and Raman spectroscopies, it has given rise to new non-linear spectroscopic methods, with spectacular precision measurements in atomic systems. The feasibility of obtaining a coherent laser device based on Einstein's concept of stimulated emission in the optical frequency region was first shown in 1958 by Arthur Schawlow in collaboration with his brother-in-law, Charles Townes. Along with two Soviet scientists, Townes, of course, received the Nobel Prize in 1964 for his earlier discovery of a similar device in the microwave frequency region.

After the fabrication of the laser device by T. H. Maiman in 1960, it was Bloembergen who showed that when an intense laser beam interacts with matter, the dielectric susceptibilities of atomic and molecular systems become functions of the strength of the light's field, and one can mix two or more laser frequencies to generate laser sources at new frequencies. Thus tunability of a laser source in one limited frequency region can be translated, using non-linear optical mixing, to another desired frequency region. Atomic systems can simultaneously absorb two or more photons with appreciable probability, and laser light can prepare atomic systems in coherent superposition of quantum states.

It will be difficult even to list here all the applications of laser beams in diverse fields from laser fusion to isotope-separation, to optical communication, to holography, to ultrasensitive atomic tracer analysis and to fundamental problems in physics and chemistry. As representative examples related to the work of Bloembergen and Schawlow, who have been directing the laser revolution in spectroscopy from the very beginning, one may mention the new methods of non-linear Doppler-free atomic spectroscopy, resonance fluorescence and ionisation spectroscopies, coherent Raman spectroscopy and bond-selective chemistry. By simultaneously absorbing two photons of the same frequency, moving in opposite directions, it is possible to cancel exactly the first-order Doppler frequency shift due to the thermal motion of atoms or molecules in a gas, and thus resolve extremely closely spaced atomic energy levels. Using Doppler-free non-linear spectroscopy in atomic hydrogen, Schawlow's group has been able to measure many important physical parameters with fantastic accuracy. On the other hand, by using sufficiently short laser pulses (duration 10^{-12} sec) whose frequency is tuned to dissociation energy of a particular bond in a molecule, Bloembergen has been able to show that one is indeed close to fulfilling a chemist's dream of breaking molecular bonds precisely where one wants to break them. With the initiation of specific chemical reactions after particular bonds are broken, this may open up dramatic developments in synthesising rare molecules of interest in chemistry and molecular biology.

SUDHANSHU S. JHA

Dr. Jha is Professor of Theoretical Physics at the Tata Institute of Fundamental Research, Bombay. He was closely associated with Prof. Schawlow during 1960-1964 while studying for PhD at Stanford University, USA, under Prof. Felix Bloch, who got the 1952 Nobel Prize in physics for nuclear magnetic resonance. He wrote several papers in collaboration with Prof. Bloembergen when he was a Research Fellow at Harvard University in 1967-1968.

Economics

JAMES Tobin (63), who has been awarded the Nobel Prize in economics, is Sterling Professor of Economics at Yale University, USA, and a past president of the American Economic Association. Educated at Harvard, he has been teaching at Yale for long. Tobin has always been interested in questions of economic policy and was once a member of the Council of Economic Advisers to the late President Kennedy. He has expressed much concern about the present trend of the US economic policy; nothing good, he says, is likely to emerge from what has been called "Reaganomics". His handling of economic problems is marked by a great sense of relevance, an appropriate degree of precision and depth of insight.

Tobin

While Tobin has made important contributions in a broad range of areas, notably the theory of consumption, it is primarily for his work on macro economics that he is most widely known and respected. Contemporary macro economics largely originated with Keynes so far as the Anglo-Saxon countries are concerned. Tobin's work is generally regarded as Keynesian. His specific contributions are in the area of 'portfolio' theory which deals with principles underlying the forms in which assets are held, beginning with physical assets, at one end, and money at the other. He has brought the 'marginal principle' to bear in the choice of assets under conditions of risk. His analysis has shed light on the theory of liquidity performance, as initially developed by Keynes, as well as on the analysis of the ways in which a change in money supply is absorbed by the economic system.

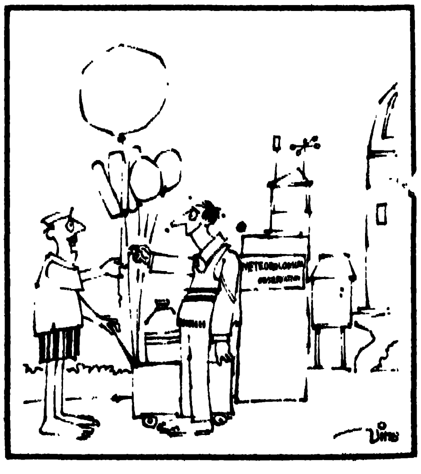
Tobin has been a consistent critic of 'monetarism', the advocacy of which is spearheaded by Milton Friedman. He has often chosen to meet Friedman on his own ground and has sought to demonstrate that the unique causal significance attached by monetarists' to changes in 'money supply' cannot be demonstrated on the basis of an 'as if' methodology combined with the empirical evidence that they have generally produced.

His work has largely proceeded within a broad framework described by Paul Samuelson and others as the 'grand neoclassical synthesis' which assigns the government an important role in managing the aggregate level of effective demand without denying the market a very important and often beneficial role in detailed allocation of resources. Contemporary 'stagflation' in western economies has posed a serious challenge to this point of view, and this has permitted 'monetarism' to stage a come-back. As mentioned earlier, Tobin is foremost among those who are arguing against simple 'monetarist' rules. But as yet there is no generally accepted unified explanation of the current economic malaise. While the problems faced by the developing countries are in many ways quite different, they cannot afford to remain insensitive to the debates currently going on amongst leading theorists in the West—not only because of their possible policy outcomes but also because the light they may throw on economics as a science. Tobin is one such theorist and we need to study him carefully and assess his position in comparison with Friedman, at one end, and Kaldor, Robinson and their followers at the other.

SUKHAMOY CHAKRAVARTY

Prof. Chakravarty is with the Delhi School of Economics, University of Delhi. He has taught at the Massachusetts Institute of Technology and Johns Hopkins University in the USA and Erasmus University in Rotterdam. He was a student and colleague of Jan Tinbergen, the first Nobel laureate in economics.

Next month: Chemistry



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IDEAS AND INVENTIONS

Simple high-temperature hardness testing device

OURS is truly a 'materials age': the timely evolution of suitable materials is crucial to the progress in important fields like aero-space, defence, electronics, and nuclear engineering. And at least one main reason for the remarkable progress in aero-space technology is that materials that can perform well at high operating temperatures have become available. Extreme temperatures, of course, put a heavy demand on the properties of materials. Most materials, when exposed to high temperatures, tend to soften, oxidise, recrystallise if cold-worked, and deform catastrophically by creep, the slow plastic deformation of metals under constant load. It is important, therefore, to make sure that they retain suitable properties at high temperatures. This involves the difficulty of measuring properties at high temperatures.

High-temperature hardness, one of the important mechanical properties, influences many properties of materials such as wear-resistance, friction, metal-cutting properties, formability, strength, etc. It plays an important role in the development and quality-control of high-temperature wear-resistant alloys and weld deposits used in metal forming, high-speed machining, steam-valves, bearings, etc. Dr G Venkatraman and Mr. S Arunagiri of the Central Laboratory, Bharat Heavy Electronics Ltd, Tiruchirapally, have developed and successfully used a simple attachment device to measure the hardness of several engineering materials at high temperatures. The device has received the 1979 Independence Day award of the National Research Development Council, New Delhi.

The invention consists of an attachment device and a tubular furnace that can be used on a standard tensile testing machine. The device consists of two main assemblies, the tie assembly and the fork assembly, machined from heat-resistant alloys. The tie assembly carries a tungsten-carbide indentor of 0.5 cm diameter mounted on a perfect axial support. A test specimen of specified size, 2 cm diameter or 1.8 cm by 1.8 cm square with 1 cm to 2 cm height, is made from the material to be tested and inserted between the two assemblies and locked by a pin. Two circular collar rings are fixed over the assembly to prevent lateral movements.

The attachment can now be mounted on a standard tensile testing machine. When the tie and fork assemblies are pulled in the machine, an axial *compressive* force is generated pressing together the indentor and the specimen. A circular impression is produced on the test specimen and its diameter depends on the tensile load and the hardness of the material.

For high-temperature testing, the assemblies are placed in a tubular furnace. The furnace is heated slightly above the test temperature before the assemblies are enclosed in it. A thermocouple with its tip close to the specimen monitors the specimen temperature. For metals that oxidise easily, an inert gas like nitrogen or argon is purged steadily through the furnace during heating and testing. The specimen is soaked at a steady temperature for about 10 minutes and the assemblies are stretched apart up to the standard load within 10 to 15 seconds and the load is held for a further 15 seconds.

Venkatraman and Arunagiri recommend different standard loads for different materials: for a 0.5 cm diameter indentor they recommend 750 kg for steels and cast irons, 250 kg for copper and aluminium alloys, 125 kg for copper and aluminium metals and 25 kg for lead, tin and their alloys. The standard load, however, depends on temperature and material. It may have to be determined by a few trials in some cases.

The diameter of the impression is measured by a graduated eye piece at low magnification after the specimen is taken out and has cooled. The standard handbook formula then gives the (Brinell) hardness number. Cooling results in a slight shrinkage of impression, but the correction for this has rarely to be applied because the resultant error is estimated to be much less than one per cent of the hardness value; this has been confirmed by testing standard specimens with a precise Brinell hardness tester and with the new device.

In the test carried out, hardness values were reasonably repeatable for room temperatures as well as high temperatures. The device is made of heat-resistant stainless steel and can be used for tests up to 650°C. The device, however, can be used up to 1000°C by using nimonic alloy or thorium oxide dispersed nickel alloy.

The main value of the device is that it makes possible high-temperature hardness tests on the tensile testing machine. The device is relatively light and simple and will facilitate the development and quality-control of high-temperature alloys.

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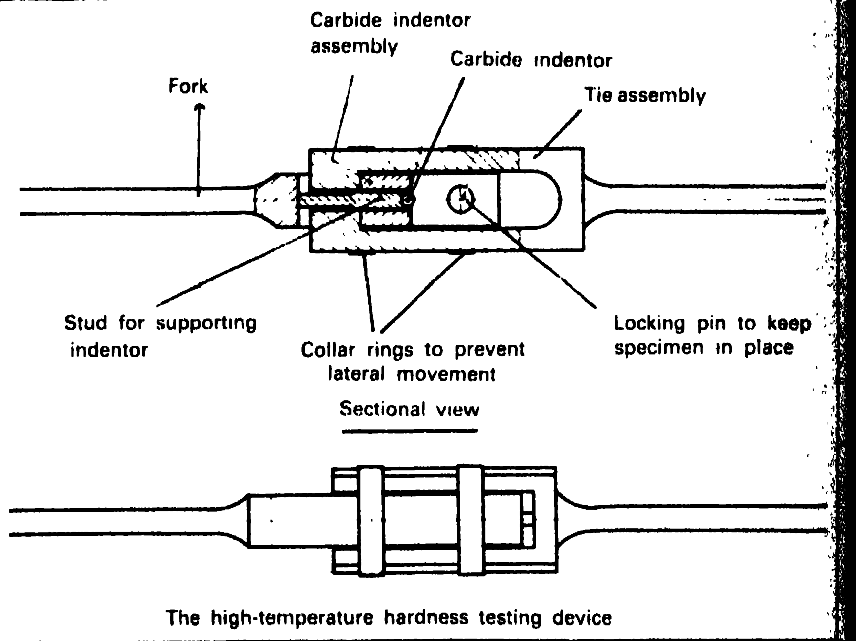
Carbide indentor assembly
Carbide indentor
Fork
Tie assembly
Stud for supporting indentor
Collar rings to prevent lateral movement
Locking pin to keep specimen in place
Sectional view

The high-temperature hardness testing device

The high temperature hardness testing device can be attached to a simple tensile testing machine. The device is enclosed in a tubular furnace. Under the tensile load pulling apart the tie and fork assembly, the carbide indentor is pressed into the test specimen to produce a circular impression, whose size will give the high temperature hardness according to standard handbook formulae

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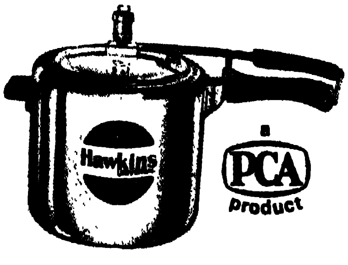

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MEET THE SMART NEW MACHINES

Blake M. Cornish

The impact of the microprocessor on society may be as great as that of the automobile or electric light—even greater. The applications of the new technology seem limited only by imagination—not by cost or capability

Nine-year-old at primary school gazes at the print-out from his desk computer

A MYRIAD of new devices are appearing as a direct result of advances in microelectronic technology. As prices have dropped and capabilities have increased, microelectronic devices are becoming an everyday part of many people's lives.

Products such as word processors, digital watches, electronic games, robots, optical-scanning, cash registers, and many others are now found in offices, stores, schools, factories, and homes.

The technology is still young, and its potential for growth is staggering. Microcomputers and robots are two relatively new products that are already causing across-the-board impacts in homes, schools, offices, and factories.

Intelligence on a chip

All experts agree that microcomputers will become part of our everyday lives, like the telephone and television. But like these earlier technologies, the microcomputer must overcome a Catch-22 dilemma: People have to buy them in order to discover how useful they are, but until they realise how useful they are, they won't buy them.

The telephone faced a similar Catch-22 situation in its early days. For most people, the investment in a telephone was not practical because so few other people had phones. And because so few people bought phones, the cost of the service remained high. Years later, television faced the same dilemma: Since so few people had sets, viewing was limited to only a few hours of sports and newsreels per week, and since viewing was limited, most families felt that buying a set was not worthwhile. But despite these problems, almost every American home eventually acquired a TV and telephone. Wealthy people, who bought telephones and TV sets as status symbols, provided a small market that could gradually grow into a mass market, as prices declined and the value and utility of the equipment increased.

The microcomputer is now overcoming its Catch-22 obstacles and spreading rapidly. And like the telephone and television, microcomputers will transform our society. About 278,000 units were sold in 1978, and over 1.2 million will be sold in 1982, according to one marketing firm's forecast—a growth of well over 400 per cent. A total of nearly 3 million microcomputers have been sold in the United States alone. *InfoWorld*, a biweekly newspaper on microcomputing, reported the dollar value of the microcomputer industry, including software, support systems, and peripherals, at $2.6 billion (about Rs. 23,500 million) in 1980. This market may swell to $14 billion by 1985. (Some prognosticators even forecast a market of $30 billion!) Most marketing forecasts put the yearly growth rate for microcomputer sales between 40-60 per cent for the next five years. Home computers could easily be in 80 per cent of US households by 1990. Jim Edlin, director of Micro-Marketing Consultants, sums up this growth: "The microcomputer is a watershed technology—like the electric light, the automobile, and the telephone, it stands to change our everyday lives more than we can know."

Small is beautiful

The technological advances leading up to the microcomputer began in 1946 with the first electronic digital computer, ENIAC (Electronic Numerical Integrator and Computer). ENIAC contained thousands of electronic vacuum tubes, filled a large room, and was slow and clumsy by today's standards.

But researchers persisted. A major breakthrough occurred in 1947 when Bell Laboratories developed the transistor. Transistors are smaller, faster, and cheaper than vacuum tubes. A more sophisticated transistor, the MOS (Metal Oxide Semiconductor), appeared in 1959, and from this the microelectronics industry emerged.

Transistors allowed computers to become smaller and faster, opening the way for the minicomputer, beginning about 1962.

The next major breakthrough came in 1971 when researchers at Intel, a California firm, developed the "microprocessor-on-a-chip"—or more simply, the microprocessor. "The microprocessor, more than any other microelectronics invention, is responsible for the microelectronic industrial revolution," says Adam Osborne in his book *Running Wild*, widely hailed as the "bible" of microcomputer buffs.

The first commercially available microcomputer, which was made possible by the microprocessor, was sold in 1975. A computer consists, basically, of three parts: a CPU (Central Processing Unit) to control the functions of the other parts of the computer; a memory to store information; and I/O (Input/Output) interfaces, which allow control of the peripherals. Although definitions vary, the term *microcomputer* is often used either to mean a silicon chip that incorporates these three functions, or a small computer system (including such peripherals as a display screen, printer, or keyboard) that incorporates such a chip.

Microcomputers do with silicon chips what larger computers did with transistors (and before that with vacuum tubes). The transistor and the tube are, fundamentally, switches that can turn on and off several hundred times a second. This constant switching on and off is the basis of all digital computers. Anything a computer works with—letters, numbers, or symbols—can be coded in an on-off, or binary, language. A silicon chip contains thousands of tiny circuits, each capable of switching on and off, that enable the microcomputer to handle its computations. A single silicon chip can contain the electronic capability of 100,000 vacuum tubes, and this number is growing at exponential rates. If current growth rates were to continue, the computer a century from now would have a data memory equivalent to 16,000 human brains, and would remain relatively small in size and cost.

"Smart machines" proliferate

Microcomputers are cheap enough and small enough that they now can be put into virtually any instrument, machine, or appliance that can benefit from memory, calculations, or automatic controls. The microcomputer gives the device some "smarts", making it a better servant. Microwave ovens, sewing machines, typewriters, automobiles, and an endless list of other "smart machines" are already on the market. For instance, a smart microwave oven can thaw a roast, cook it, then turn itself off. The oven needs no reminders from the human cook.

Microelectronic devices are improving automobile performance as well. Recent surveys of automotive industry leaders by *Car and Driver* magazine reveal that fuel economy expectations for the year 2000 range from 18 to 36 kilometres per litre. This high mileage will in part be a result of microelectronic controls.

The microcomputer has made it possible for ordinary people and small businesses to own computers, whereas just a few years ago only the largest corporations, government agencies, or public utilities could afford them.

Today microcomputers (sometimes called personal computers, small computers, or desk-top computers) have become commonplace in businesses; schools are experimenting with them; and an increasing number are being sold for home use.

In business, microcomputers have greatly expedited such tasks as inventory control, budget allocation, text processing, payroll design, and transaction processing, just to name a few of the thousands of applications.

In schools, microcomputers are used for teaching traditional courses, such as mathematics, English, and history, as well as introducing students to "computer literacy", a skill that soon may be considered as basic as the three R's.

A classroom computer program can drill students individually, praising them for correct answers and preventing them from continuing when they make a mistake. Often such programs are also capable of "branching": The computer assesses a student's responses to determine areas of strength and weakness and then selectively displays appropriate exercises that are challenging to the student without being frustrating or boring. Classroom computers can also be used for unit review, self-testing, and analysis of laboratory data. An IBM 1620 at Stanford University has been used to teach singing! The computer prints out a series of notes, which the student then sings. The computer can compare the student's pitch with the true pitch to determine what exercises the student needs.

But despite the rapid adoption of computers by some educators, com-

Microcomputers that talk and hear

More and more people are talking to machines, and the machines are talking back. All the microelectronic circuitry necessary to simulate human speech can be contained on one to three silicon chips, though a tradeoff must be made between the quality of the sound produced and the size of the vocabulary of the "talking chips".

The most renowned product is the single-circuit voice synthesizer patented by Texas Instruments and utilized in TI's educational toy, Speak and Spell. The product can store over 200 words in its memory and pronounce them clearly. The machine speaks a word, and the child tries to spell it by typing it on a keyboard. If the child fails to spell the word correctly, the machine says, "That is incorrect" and spells it correctly.

Microchips "talk" in several different ways. One method of speech synthesis involves storing the sound wave form and volume of a word on a microchip. When the word should be spoken, the memory converts the information to voltages, which are fed to an amplifier. [illegible]

[illegible] bits per word for storage, but the quality of sound is poorer.

Linear predictive coding, which is similar to phoneme coding, produces a higher quality of speech but also requires more bits per word. As with phoneme coding, the microchip stores the basic utterances of human speech, but it also employs a mathematical model of the human vocal tract in order to provide a more realistic transition from one sound to the next and to alter intonation.

Personal Electronics Inc. has recently announced a talking wristwatch. The watch uses the linear predictive coding method in order to announce the time. The watch can be set as an alarm, waking you up with music, then [illegible]

[illegible] speaker. Furthermore, the computer has difficulty determining where one word ends and another begins. For instance, the computer can't tell the difference between "a [illegible]" and "[illegible]" or between homonyms like "right" and "write".

Despite the complexities, speech-recognition technology already is available in limited form. Usually, the computers understand only a few specific command words and must be "trained" to recognize the voice of a specific person. The IBM Corporation, however, is trying to develop a voice-activated typewriter, which would accept voice dictation, display the dictated material on a visual display screen for proofing, and then provide a typed hardcopy. [illegible] puters will probably not become commonplace in the classroom for at least 5 to 10 years, due to budget constraints, resistance to change, lack of comprehensive studies indicating the value of Computer-Assisted Instruction (CAI), and lack of adequate software. Nonetheless, as computer costs decline, as more educators are exposed to computers, as more and better software becomes available, and as "computer literacy" is increasingly viewed as an important skill for education and employment, the classroom computer will most likely overcome any obstacles.

Visually aided robots perform pick-and-place operations on a production line for calculators at a Texas Instruments factory

Future developments

In the next few years, microcomputers will become still more powerful and easier to use. Increasingly, computers will become self-programming and therefore require very little if any technical training for operation. Microcomputing expert Jim Edlin points out that computers simply won't be economically viable unless they can be commanded rather than programmed. He compares the situation to automobiles: If cars were still made with hand-crank starters, manual steering, and manual transmission, many people wouldn't buy them.

A prototype of the self-programming computer is expected to be commercially available soon. Proteus, developed at Massachusetts Institute of Technology and marketed by Solid State Technologies, requires no codes or special languages, so users need not be familiar with computer programming. Proteus works by letting the user design the symbols that tell computers what to do. Other computers, commercially available today, guide the user through a programme step by step, thus allowing "computer illiterates" access to computers.

The Pencept System, announced and first demonstrated in May 1981 by Pencept Inc of Waltham, Massachusetts, enables a computer to read hand-printed characters. The user need not use a keyboard, nor go through the tedious process of filling in small boxes with pencil for a computer to read. Hand printing on preprinted forms allows the computer to understand the input material. A video display screen shows what the computer has "read" so that the user can check to be sure the computer has understood correctly. Using a sophisticated system of algorithms, the system is able to recognise a wide range of writing styles.

Microcomputing advances still to come possibly within five years are mind-boggling. Though industry specialists don't agree about how quickly the advances will come, or how far the technology can ultimately go, even the most conservative forecasts are startling.

Today, a pocket calculator that costs about $10, weighs under a pound, and is only a few centimetres long is more powerful than a bulky calculator that could easily have cost over $1,000 a decade ago. By 1985, say some industry enthusiasts, a programmable hand-held computer will have the power of today's most powerful computer, Cray I, which cost $9 million. The nanoprocessor, which is 1,000 times more powerful than the microprocessor, could be available within a decade. The next step after that will be the picoprocessor, one million times more powerful and based on molecule-sized circuits. Lewis M. Branscomb, vice president and chief scientist of IBM, has speculated that the ultimate picoprocessor might be patterned on DNA.

Computers are becoming easier and easier to use. This one requires no keyboard. And the user not needing to be a professional programmer will allow a totally new audience to use computers

Factory of the future

Industry applications of microelectronic intelligence are changing the look of some factories, and this "electronic work force" will almost certainly grow during the next decade. Robots, computer-aided design, computer-controlled manufacture, and a host of other technologies are shaping the factory of the future.

Despite all the talk about robots, US manufacturers have only "hired" about 4,000 so far, mainly for the automobile industry. But during the next 10 years, the industrial robots are expected to take over more and more jobs. In Japan which discovered the economical advantages of robots before most other industrial nations, the goal is to have factories without any human labourers at all by 1985.

Robots are a manager's dream: They never take coffee breaks or lunch hours; they willingly work three eight-hour shifts a day; they don't complain about doing unpleasant work; and they never take time off for union meetings. Robots now can do many tasks faster, cheaper, and better than human beings.

Just what is a robot? Generally speaking, a robot is any machine that performs jobs previously assigned to a human being, is self-operating, and is "intelligent"—that is, it contains electronic logic in the form of a microcomputer. A robot must be versatile, a characteristic provided by the microprocessors. Versatility makes robots economically feasible, because robots are designed for manufacturing tasks that frequently change. Manufacturing tasks that are highly standardised, such as yarn spinning, will continue to be done with specialised automated machinery rather than multifunctional robots. However, automobile models change each year, often drastically, and robots' versatility allows a task to be automated even when a particular function may be performed only 50 to 100 times. The robots can be repeatedly reprogrammed to perform different functions, depending on the needs of the factory.

Most industrial robots in use today are hardly recognisable as robots. They do not look like mechanical men but more like pieces of automatic machinery. Usually a robot is simply a mechanical "arm", with two to six joints. The robot's "hand", called an "end effector", can be changed, depending on the job. The "hand" can be a welder, a riveter, a paint spray gun, a scoop, or a claw.

Evolution of the robot

As robots grow in sophistication and power, they will bring on changes in human life at least as large as those of the industrial revolution. One can only imagine some of the moral and practical questions they will raise.

Warfare, in a weird throwback to the fifteenth century, will be fought by metal-covered mercenaries, covered not with Milan armour but with exotic metals like titanium. Huge metal insects with only microprocessors aboard will fight furious battles in space where no human beings are killed. A loser nation will have no alternative to abject submission.

A body of robot law will grind through the legislature and courts: Who is responsible when a robot blows a fuse and tramples somebody to death, or puts rat poison in the soup? Triple-tiered safety devices will be mandated by statute.

One company has developed a miracle chip, only one-quarter of an inch square, that will hold 128 million bits of information. The new "bubble" memory will approximate a compaction of information now enjoyed only by the human brain.

One prediction can be made with confidence. The electromechanical robot will swiftly duplicate the evolution of life on Earth. As its brain gets more complex it will successively surpass the brain of the angle-worm, fish, and amphibian, and there is no apparent upper limit in sight. It is interesting to wonder when, on this upward-charging curve of complexity and new cerebral techniques, will reasoning power and emotions be born spontaneously out of the complications? When exactly were they born in our own line of organic evolution? What will happen when mental parity with human beings is finally reached?

The Star Wars robot. Will life soon imitate art?

> ***"Some human workers have lost their lives on the job. But if a robot leaves its arm in the way of a die, it can be repaired or replaced. And because a robot can't daydream or be distracted, it is less likely to leave its arm in the way."***

Modern industrial robots are easily programmed. All the programmer need do is guide it through the motions of a task, step by step, and press a programme memory button. The robot remembers the process and can repeat it any number of times.

Robots can perform uncomfortable, dangerous jobs. Unlike their human counterparts, robots can handle loads up to 950 kilogrammes or work efficiently in temperatures from 5 to 50°C. The die-casting industry, for instance, uses robots because of the danger in walking between the large moulds into which molten plastics and metals are poured. Some human workers have lost their lives on the job. But if a robot leaves its arm in the way of a die, it can be repaired or replaced, and a human injury is avoided. And because a robot can't daydream or be distracted, it is less likely to leave its arm in the way.

Despite recent advances, robots are still limited in their usefulness, because they must be programmed to perform a function in a very precise manner and the materials they are working with must be precisely coordinated. For instance, a spot-welding robot on an automobile assembly line welds exactly the same place time and time again, until it is turned off or reprogrammed. If the auto parts moving down the assembly line slip just a fraction of a centimetre out of place, the robot will miss the correct spot to be welded. To deal with this problem, roboticists are developing sensory capabilities for robots.

Robots see, hear, feel

Already, some robots used by Texas Instruments to inspect calculators are able to "see": One robot picks up the calculator, another presses a predetermined sequence of buttons, and a third "reads" the answer, checking to see that the calculator computed correctly. Seeing robots are still crude, clumsy, and costly, but their skill is expected to improve and their price to fall in the next few years.

"Our management estimates that it will take 10 years to make sensory capabilities cost effective," says Joan Juzwiak of Prab Conveyors, a major manufacturer of robots. "Vision systems just are not practical, not yet."

Autoplace Inc, another robot manufacturer, is already marketing its Opto-Sense® vision system. "The biggest value of the vision system as we see it is that it is part of the production process. We can inspect a part within a fraction of a second", says Frank Kadlec of Autoplace. "When you automate, you get improved productivity and improved quality control.... It (a robot) doesn't blink, and it gives you a permanent record that you have inspected the product."

Some robots are getting a sense of touch. Draper Labs has developed a robot with a rudimentary sense of touch. The robot can tell when a part doesn't "feel" right in its hand, and can alert its foreman. The robot is also able to jiggle a part until it fits properly into place, using sophisticated sensors to follow the contour of the object being worked on.

Researchers at the Massachusetts Institute of Technology have developed a type of "artificial skin," which gives the robots a sense of touch. The "skin" consists of sheets of rubber laced with wire. The top sheet has an electric current running through it, so that as pressure is applied, the top sheet passes the current down to other levels of the rubber sheets. The amount of pressure applied determines which sheets of rubber and wire are electrified. A microprocessor measures the voltage of the different levels of skin and can form an image of the object being touched.

Robots that can hear would also be a boon to the factory of the future. With a microphone for an eardrum, a robot can convert sound waves into number sequences, and then compare these with various number sequences stored in its memory to determine the meaning. Hearing is still a difficult task for robots and other microelectronic devices, but capabilities are expected to improve rapidly in this area, too, during the 1980s.

Robots won't be limited to human senses, however. Depending on their intended use, robots may be given infrared sensors, sonar, ultraviolet sensors, radiation detectors, or a variety of other special senses.

The next step in creating the sophisticated robot of the future is to integrate sensory capabilities with more sophisticated electronic logic.

Seeing robots hold key to factory of the future

FLEXIBILITY and adaptability make robots economical. In order for robots to become more adaptable, they must be able to respond to a continuously changing environment—they must have senses. The most important sense, say roboticists, is vision.

"Rudimentary vision will have the most profound effect in broadening the application base of robotics", writes Joseph F. Engelberger, president of Unimation, in his book *Robotics In Practice*.

Sight will enable robots to adjust to small changes in their work environment, giving them greater flexibility. A blind robot will operate exactly as it was programmed, regardless of changes in its immediate environment. Even if the assembly line stopped, and no more parts came to the robot, it would continue to repeat the same operation time and time again, until a human intervened. But a seeing robot can adjust to such changes.

Seeing robots can also inspect parts and assemblages as they go down the production line, thus improving quality as well as productivity. "If manufacturers are going to improve product quality, there is a definite need for computer-controlled vision systems", says Richard G. Abraham, general manager of Autoplace Inc, which markets the Opto-Sense vision system. "Computer-controlled visual inspection eliminates operator guesswork in many cases, and results in big quality improvements."

Electronics firms, auto manufacturers, and robot manufacturers are all involved in the quest for economical machine vision systems, and several methods have already emerged.

Most vision systems use solid-state television cameras for robot eyes, but in order for a robot's microcomputer brain to understand the picture, it must be digitised, that is, coded using "bits" (binary digits). Everything a computer deals with must be digitised, whether it is a number, a letter, a song, or a painting. The more detailed the image, the more bit capacity is needed.

A colour television camera provides good resolution, but it generates a tremendous amount of data—2½ million bits per second—which is far too much for an inexpensive microcomputer to digest and analyse. So roboticists are developing methods to reduce the number of bits needed to understand a visual image.

Solid-state digital cameras can reduce the number of bits a computer has to cope with by transforming the picture to a certain number of light-sensitive elements. For example, a camera might use an array of 10,000 light-sensitive elements to produce an image. While the image is not of photographic quality, it is often enough for a robot to be able to identify a part. Most robot vision systems use black-and-white images, thus further reducing the bits required to produce the image.

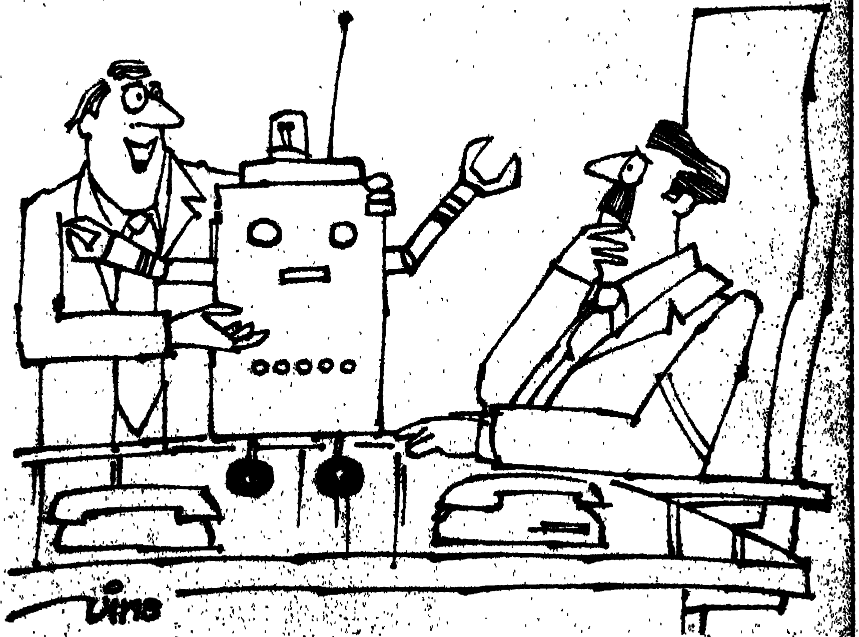
The General Motors Consight vision system employs an array of 100 by 100 light-sensitive elements. The computer assigns each element a number between 0 and 63, representing the light intensity of that portion of the picture. The number 0 represents black, the number 63 represents white, with shades of gray in between. These 10,000 numbers, stored in order in the computer's memory, constitute a digital picture of the scene and enable the computer to understand the picture.

In many vision systems, the computer's original programme would include a digital picture of the part being dealt with, and the computer would compare the two images in order to identify the part. Once a part is identified, it may be necessary for the computer to tell the robot where and how to pick up the part. One way for the computer to do this is to find the edges of the part, by looking for areas where there is a sudden change from light to dark. The computer can use other programmes to join different edges together to form boundaries, and, by using suitable models stored in its programme, the outside boundaries and holes can be determined, the part identified, and the position and orientation computed. The computer then has enough information to direct the robot to pick the part up.

Researchers are developing methods to filter out all but the essential information that the computer has to deal with. One method, employed by GM's Consight system, uses a special lighting system and a linear-array camera, which takes advantage of the fact that the parts are moving on a conveyor belt. A camera is focused on a line of light projected on the conveyor belt from an angle. Since the camera scans only this line, the computer only has to deal with 100 numbers at a time instead of 10,000, though it still receives all the information by the time the part has passed under the camera completely.

A "smart machine" developed by Western Electric sees in colour, though it is not considered to be a robot because it is single-purpose, not flexible, and not reprogrammable. The machine sorts telephone parts by colour, using an electric eye that measures the primary colour components of light reflected from the surface of each telephone part, in much the same way as the human eye determines colour.

Researchers are trying to develop a variety of other vision systems for robots, such as stereoscopic systems to see in three dimensions and laser light systems that will serve to filter out all but the essential parts of a picture. Commented one roboticist, "Whether future robot eyes will be based on these systems remains to be seen. One thing is certain: Tomorrow's robots will have vision."



It does all the work. Only, the deluxe model has a 'no-wage-increase' chip incorporated.

enabling robots to make limited decisions. A robot would be able to decide such things as whether a damaged part is repairable or should be discarded, or, if the robot itself is slightly damaged, it would be able to decide whether to turn itself off and alert a human or wait to the end of its "shift"

Implications for employment

The long-term impacts of robots and computers on the factory of the future will be profound. So far, robots have been used mainly for dangerous or extremely unpleasant jobs. But in the future, robots may take away jobs that humans want.

Opinions vary widely on just how many factory jobs could be eliminated. The founder of Unimation, a major robot manufacturer, says that no more than 5 per cent of the blue-collar jobs will be eliminated by the year 2000. Other automation experts have estimated that robots will reduce today's factory work force by 65 to 75 per cent. While keeping a close eye on robots, labour unions do not view them as a threat to workers—at least not yet—because robots must constantly be maintained and fed parts to work with, and someone has to build the robots in the first place. Furthermore, unions realise that if robots can cause increased economic growth (as automation generally does), more jobs will be created than lost.

But there is a possibility of a virtually unmanned factory. The Italian automobile company, Fiat, believes that sensory robots would slash manpower requirements by 90 per cent over the next 10 years; computer programmers and technicians might comprise most of its work force by 1990.

Osborne, in his book *Running Wild*, says, "Given the tasks that robots will be able to perform, their impact on the blue-collar force will be profound. Most assembly line jobs will be eliminated. Automobiles, washing machines, and television sets will all be assembled by robots. Robots will even assemble themselves." Indeed, 50 robots in Japan have begun reproducing themselves, manufacturing new robots 24 hours a day.

Other applications

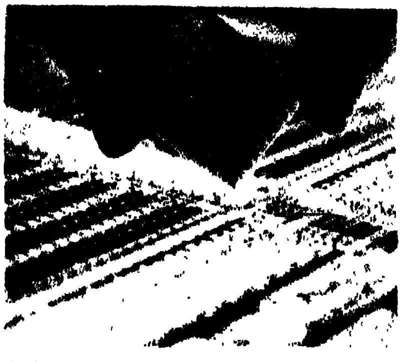
Besides controlling robots, computers will work harder and harder in the factory of the future. In addition to Computer-Aided Design (CAD) and Computer-Aided Manufacture (CAM), potential computer work includes automating warehousing, packaging, inspection and product testing, and inventory control. Computers already control a wide variety of manufacturing equipment, and are even beginning to automate management, helping company executives make decisions about advertising, marketing, purchasing, and labour. Computers are also involved in rating and improving factory efficiency.

[illegible] of Energy, the US D[illegible] merce, Oak Ridge A[illegible] Universities, General Energy A[illegible] and the National Association of Manufacturers, and Energy Future, the Report [illegible]

[illegible]

A Ford Motor Company parts warehouse uses a voice-activated conveyor belt for shelving goods. When a package arrives at the loading dock, an employee places it on a conveyor belt and reads the destination into a microphone. The package is then automatically carried to the proper place.

Computers have automated order-handling for factories. A computer can contain all the records of invoices, purchase orders, and payments—records that traditionally take up rows and rows of filing cabinets. If a clerk wishes to apply payment to an outstanding invoice, he can use a light pen to pick out the invoice number from a master list on a computer terminal's video display screen. The computer can then produce the full invoice, and the account can be updated. The procedure can reduce the cost of handling transactions by 30 per cent. At the same time, computerised credit checks have reduced losses due to bad debt.



A single microchip can contain the computing capability of 100,000 vacuum tubes. This miniaturisation of electronic components allows a variety of new applications for computers

The factory of the future will almost certainly be vastly more automated than today's factory. Just as the industrial revolution took many workers out of agriculture and employed them in industry, so the microelectronic revolution may take many workers out of industry and employ them in the production of information and other services.

Microelectronic technologies already have changed the daily lives of millions of people: Office workers use word processors; shoppers pick up cash from 24-hour computerised bank tellers; students receive computer-assisted instruction. The rapid advances and pervasive impacts of the technology during the past decade, coupled with the anticipated acceleration of the development of new technology, clearly indicate that remarkable changes in our everyday lives will occur as a direct result of microelectronics.

Blake M. Cornish, a member of the *Futurist* staff, contributed to the special report on the information society prepared by the World Future Society for the 1981 *Hammond Almanac*. Copyright © 1981 by *Futurist*. Reprinted by permission.

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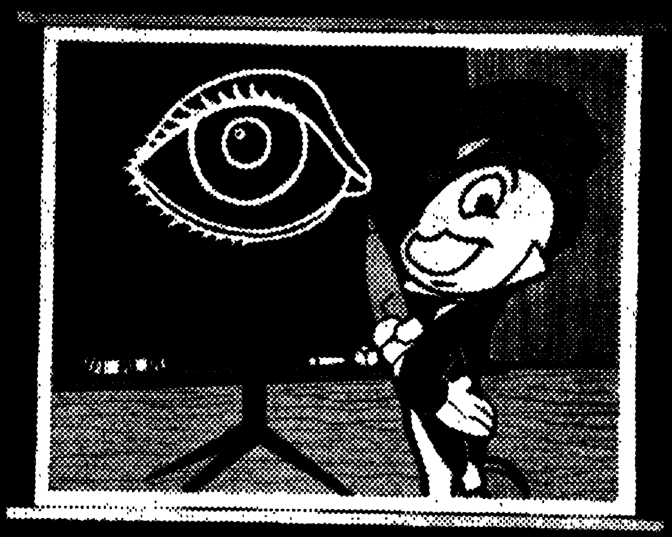

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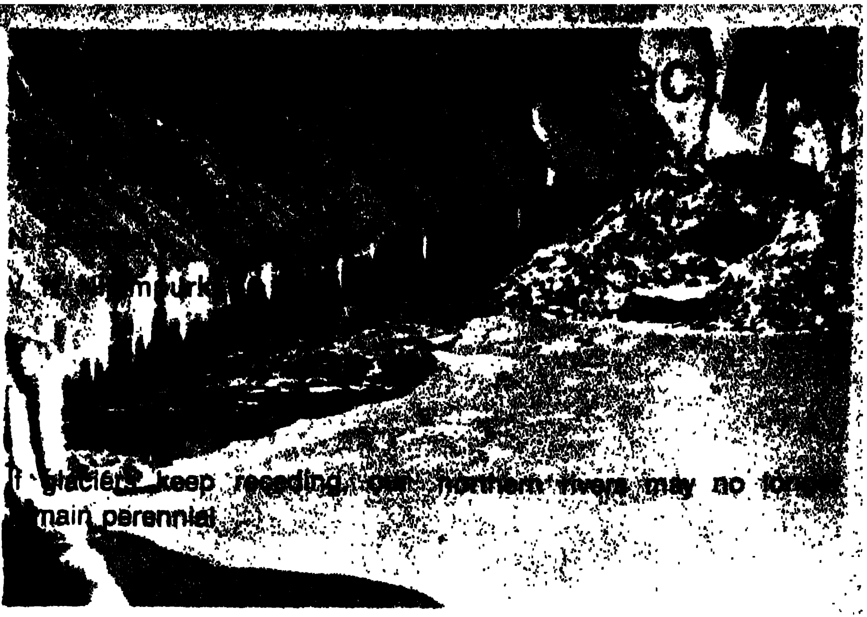


If glaciers keep receding, our northern rivers may no longer remain perennial

THE glaciers world-over are shrinking. In fact, the recession of glaciers began a few centuries ago. Even pilgrims trekking to the snow-covered Himalayas bring fresh corroboration of this world-wide trend. The Gangotri glacier, the source of the holy *Ganga*, has retreated by 600 m between 1935 and 1976, and the Pindari glacier has retreated by about three kilometres during the past 130 years according to the Glaciological Division of the Geological Survey of India (GSI). And of nearly 100 glaciers in the Swiss Alps that have been monitored since 1890, more than 75 per cent have been receding, except between 1912 and 1928.

Glaciers, including the huge Greenland and Antarctica ice sheets, contain more than three-quarters of the world's fresh water; indeed, if the ice-sheets melt, the sea level would rise, inundating low-lying coastal areas. The fresh water from Himalayan glaciers has a special significance for India. Glaciers are an important source of water for the northern rivers, most of which have large catchment areas thick with glaciers. During the monsoon, the rains feed these rivers and in the winter groundwater sustains them, but in the lean period of summer most of their water comes from melting snow and glaciers; that is why the northern rivers are perennial, unlike peninsular rivers.

The ice sheets of Greenland and Antarctica form an overwhelming 97 per cent of the glaciers, and their melting and growth have far-reaching influences on climate and sea levels. The Earth periodically goes alternately through several cold periods called "glacials" when the ice sheets grow, and warm periods called the "inter-glacials" when the ice sheets shrink.

The older glacial epochs are poorly documented, but more recently the Earth definitely experienced cold climates around 450, 350 to 250 and one million years ago; and a significantly warm period about 80 million years ago. These cycles continue with smaller periodicities and different amplitudes, and the most recent glaciation came to an end about 10,000 years ago. Presently, the Earth is going through a relatively warm period emerging out of a little ice age which lasted about four centuries. These cycles are responsible for the growth and recession of glaciers, which are very sensitive monitors of climate.

The continental glaciers, though numerous, are much smaller in size than the polar glaciers. Though accounting for only about three per cent of glacier ice, the amount of ice in the Alpine, Himalayan and Andean glaciers is by no means small. The Himalayas—which have nearly 15,000 glaciers—are one of the largest continental areas under ice. It is estimated that about 33,000 square kilometres constituting about 17 per cent of the Himalayas and 16,000 square kilometres amounting to nearly 37 per cent of the Karakoram are ice-clad.

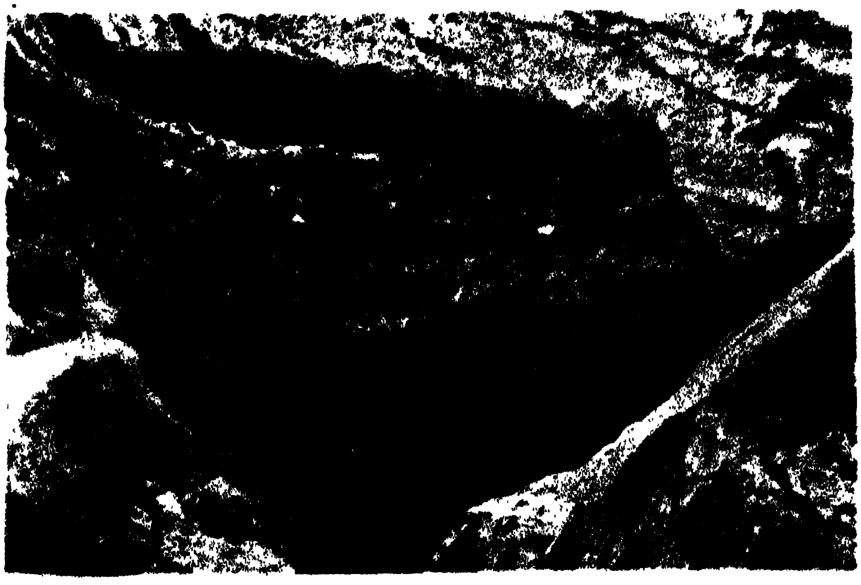
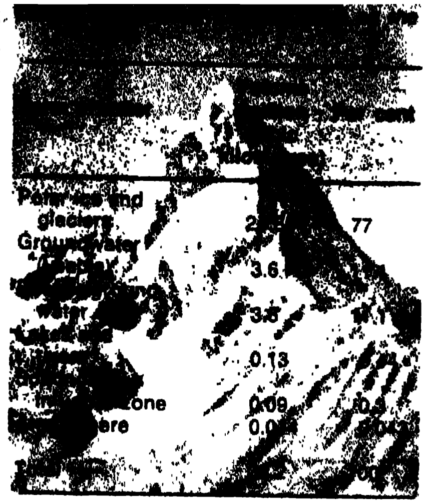


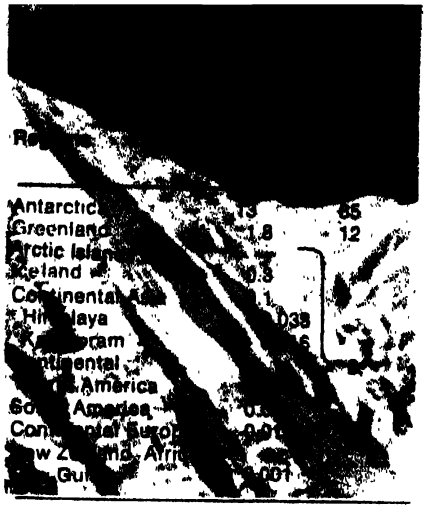
Fig. 1. An ice-cave near the terminus of the Changme-Khangpu glacier in Sikkim. Flowing melt water can produce such sub-surface caves in a glacier

An average Himalayan glacier has a capacity of about a tenth of a cubic kilometre, but even a medium glacier can provide enough water to fill a large dam like the Bhakra which has a capacity of about 8 cubic kilometres. And a large glacier like Gangotri can fill it three times over. Yet, in spite of its importance, glaciology, the study of glaciers, has been largely neglected.

Little was known about Himalayan glaciers and their dynamics, till recently. Because of the craze for more fashionable research, so little work has been possible that we have hardly any idea of how much water Indian rivers get from snow, rain, groundwater or glacier melt in different seasons. The lack of such information seriously handicaps the planning and management of reservoirs on these rivers for irrigation and power generation.

The lack of interest has also kept facilities for glaciological research at a very low level. In western countries, equipment and personnel are transported by easily available helicopters to the remotest places. Snow-mobiles and snow-scooters are also now available for moving over glacier surfaces. In India, however, most of the transportation has to be manual, requiring several days or months of trekking on





the ice-clad mountains. Indian expeditions, thus, invariably become time-consuming and inefficient.

There are however some signs of growing interest in glacier studies. The GSI, particularly its Glaciology Division in Lucknow and Calcutta, started monitoring some Himalayan glaciers since the mid-1970s. Some limited effort has been initiated in other laboratories like the Snow and Avalanche Study Establishment, Manali. And, recently, a systematic study of glaciers has been taken up in the Physical Research Laboratory, Ahmedabad.

There are several techniques used in studying glacier dynamics. These include methods of dating glacier ice (see box below).mapping, and mass

How old is glacier ice?

GLACIERS, those solid rivers of ice, have trapped in their layers the story of how climate has changed over centuries. The key to unravelling this story is to determine the age of the ice and the time elapsed since its precipitation. And, of course, the age provides the basic time-framework in understanding the dynamics of glaciers. Fortunately, nature provides accurate dating clocks; the most important of them are the different isotopes that ice incorporates as it precipitates.

Radioactive dating

Some radioactive isotopes like hydrogen-3, silicon-32 and carbon-14 produced by cosmic rays are incorporated in snowfall. Other natural radioisotopes include lead-210, [illegible] and radium-226 produced as a result of the decay chain of uranium-238 in the Earth's crust. These isotopes decay at their characteristic rates as they are carried along in glacier ice.

The results of isotope studies indicate that in Himalayan glaciers, young ice is continuously mixing with older ice and that these two components can be resolved by considering the isotope pair [illegible] and lead-210. The ages of young ice obtained from the Nehnar in Kashmir, the Changme-Khangpu in Sikkim and the Gara in Himachal Pradesh range between 100 and [illegible] years. Larger glaciers like the Gangotri, however, may have higher ages of the [illegible]. Besides the natural radioisotopes discussed above, ice incorporates a whole series of isotopes from the nuclear fallout of atomic explosions. The radioactive behaviour of the layers of ice core can also be used to determine ice accumulation rates.

The radioactive dating methods, however, have some limitations. For example, there is no convenient radioactive method for dating annual ice layers and deep ice core samples older than 1000 years. Hydrogen-3 and lead-210 date the ages of systems of up to 100 years and silicon-32 and Argon-39 of up to 300-1000 years. Carbon-14 methods do work up to 25,000 years, but all these techniques often require large volumes of melt waters, very complicated procedures for separation of elements, and comparison with radioactivity from fresh snow.

Stable isotope methods

Fortunately, however, stable isotope methods supplement radioactive dating. The ratio of the stable isotopic oxygen (18 and 16) and hydrogen (2 and 1) present in water molecules is one of the most powerful tools for dating the annual ice layers and the ice samples up to a million years old thus providing information on past climate.

Oxygen is the most abundant chemical element in the Earth's crust. It has three stable isotopes, oxygen-16, 17, 18 whose natural abundances are 99.753, [illegible] and [illegible] per cent, respectively. The two stable isotopes of hydrogen (1 and 2) have abundances of 99.985 and 0.015 per cent, respectively. Water consists principally of ordinary hydrogen-1 and oxygen-16.

The hydrogen-2 and oxygen-18 concentrations in natural waters depend on the origin and history of the water. Because water that is obtained from [illegible] lower [illegible] than ordinary water. Water evaporated from oceans contains less of hydrogen-2 and oxygen-18 relative to the ocean water. Likewise, for the same reason, when this vapour condenses to form rain, the rain water contains more of the heavier isotopes than the atmosphere. [illegible] The [illegible] of fractionation of isotopes depends, furthermore, on the temperature; heavy isotopes are depleted more at lower temperatures or higher altitudes. This effect is measured as the departure of the isotope ratios of hydrogen-1 to 2 or oxygen-16 to 18 from some reference level, such as the standard mean for ocean water (SMOW). This deviation is expressed as the ratio of the difference in the isotope ratios in the ice sample and the standard, with the isotope ratio in the standard, and is expressed in parts per thousand.

There is a direct correlation between the hydrogen-2 and oxygen-18 deviations and the temperatures of precipitation and mean annual air temperatures. The isotopic composition of polar glacier ice depends mainly on the temperature at which the snow was formed when the surface ice sheet was deposited. The isotope deviation values, therefore, change significantly in winter and summer precipitations, allowing a layer by layer dating of polar ice.

Glaciers are extremely sensitive to climate. Deep-ice cores thus give palaeoclimatic information in the form of deviations in stable isotope values; for example, increasing values of oxygen-18 deviations in a vertical ice core reflect a warmer trend of climate. In India, studies of stable isotopes of oxygen have been conducted on the Nehnar glacier in Kashmir and the Changme-Khangpu glacier in Sikkim on 100 and [illegible] deep ice cores, respectively. The [illegible] isotope ratio in the [illegible] Nehnar (an oxygen-18 [illegible] parts per thousand) is [illegible] than that in the Changme-Khangpu glacier (an oxygen-18 [illegible] parts per thousand) indicating [illegible].

[illegible]

[illegible]

balance studies. By studying glacier morphology, the climatic history and its interrelation with glacier dynamics, and by suitable mathematical models, it is possible to predict the future behaviour of glaciers.

The anatomy of glaciers

A glacier is a body of ice that originates on land by the recrystallisation of snow under definite conditions: it needs (1) a distinct area where more snow or ice usually accumulates than what melts—the accumulation zone, (2) another distinct area where more snow or ice usually melts or wastes than what accumulates—the ablation zone, and (3) a slow transfer (by creep) of the ice mass from the first region to the second.

In the accumulation zone, even at the peak of summer, the temperature is too low to melt all the snow. In the ablation zone, which is at a lower altitude, snow may deposit in winter but the summer temperatures are high enough to melt the snow and even some ice. The line separating accumulation and ablation zones is called the equilibrium line. The terminus of the glacier or the snout represents the lowest point where ice can survive.

Sometimes water flows down from the snout of the glacier to form a lake downstream. Sediments depositing in such lakes contain records of glacier melting. In a receding glacier, moraines or the debris left on its path as the glacier shrinks can provide clues to the history of glaciers.

Glaciers vary widely in forms and characteristics. The major morphological types include (1) the cliff and the cirque glaciers, (2) the valley glaciers, and (3) the continental ice sheets. The cliff glaciers are almost a triangular wedge of ice, often with a convex surface, and lying in a shallow funnel-shaped hollow in the upper parts of a hillside. When the snow line descends as in winter, the ice of a cirque (a steep enclave high on the mountains usually forming the blunt edge of a valley), moves out of the cirque basin and down the valley to form a valley glacier. Continental ice sheets, piled onto the continental

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the length of time. Since the climate varies over long periods, the growth is not uniform and the rate of growth has to be independently determined.

A number of lichen species like *Xanthoria elegance*, *Lucenora rubina* and *Panodina* have been detected in glacial moraines from Indian glaciers. *Xanthoria elegance* is the dominant species found near the snouts of the Gangotri and Gara glaciers. *Rhizocarpon geographicum* has been the most widely used lichen species for studies; it has a broad distribution, a long life and a constant age-to-size relationship. Moraine ridges have been dated by this technique back to AD 1750 and the largest *R. geographicum* thallus has been observed to be 220 mm in diameter, making it as old as 6,000 years. The growth rates of different species generally vary from 0.01 to 0.15 mm a year. The technique has also been successfully employed in the Gangotri, the Gara and other Himalayan glaciers; their terminal moraines were a few hundred years old.

The use of remote sensors based on satellite imageries or aerial photography is one of the modern techniques to study some problems like assessment of annual snow cover, and the identification of glaciated areas and surface water reservoirs over large areas in a short time. Making use of infrared, ultra violet and false colour imageries (Table) lot of information about snow cover and glaciers can be obtained. Microwave and radio techniques can be used to estimate the depth of ice. Such techniques have already been applied in Denmark and Norway to assess snow cover and water discharge. And because of the vast areas involved and their poor accessibility, remote sensing should provide one of the most effective and prompt techniques in compiling a glacier inventory of the Himalayas. Indeed, if appropriately calibrated with the data obtained on ground, even the potential water discharge through rivers can be known.

N. B.

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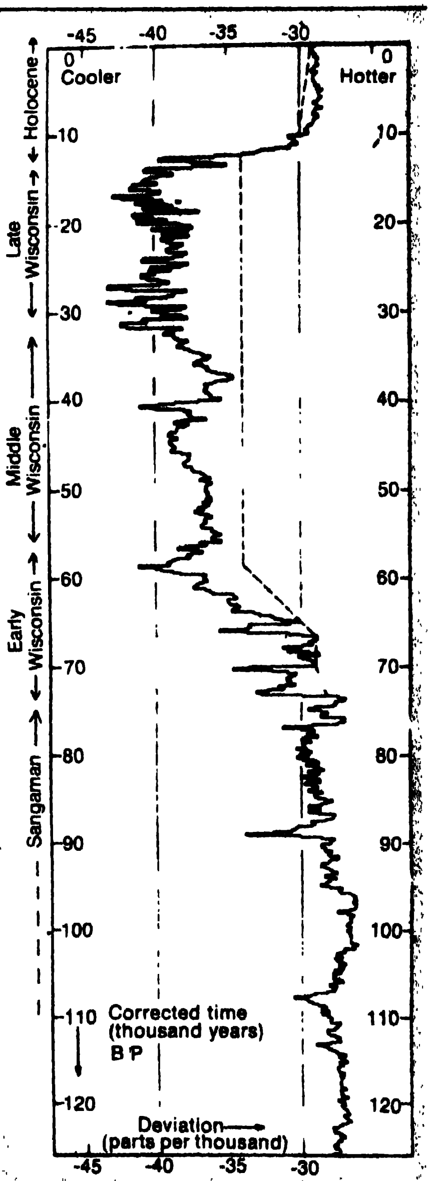


Climatic record in Greenland over 120,000 years as determined by the Geofisique Isotope Laboratory, Copenhagen, Denmark. The oxygen-18 deviation is an average over 200 years

Table: Potential applications of remote sensing

Type of electromagnetic spectrum	Part of the spectrum (microns)	Properties studied	Type of Sensor
Gamma-, *X*-, and ultraviolet rays	.005 to 0.4	Elemental chemistry and mineralogy	Special aerial photographic and counting techniques
Visible	0.4 to 0.7	Area and position of ice, snow and water reservoirs	Aerial photography (black and white and colour) and false colour
Near infrared	0.7 to 10	Water content, chemistry of dust and surface temperatures	Aerial photography (colour) and special detectors
Far infrared	10 to 1,000		Scanning radiometer
Microwave	1,000 to 100,000	Temperatures and electrical properties at depths	Microwave sensors

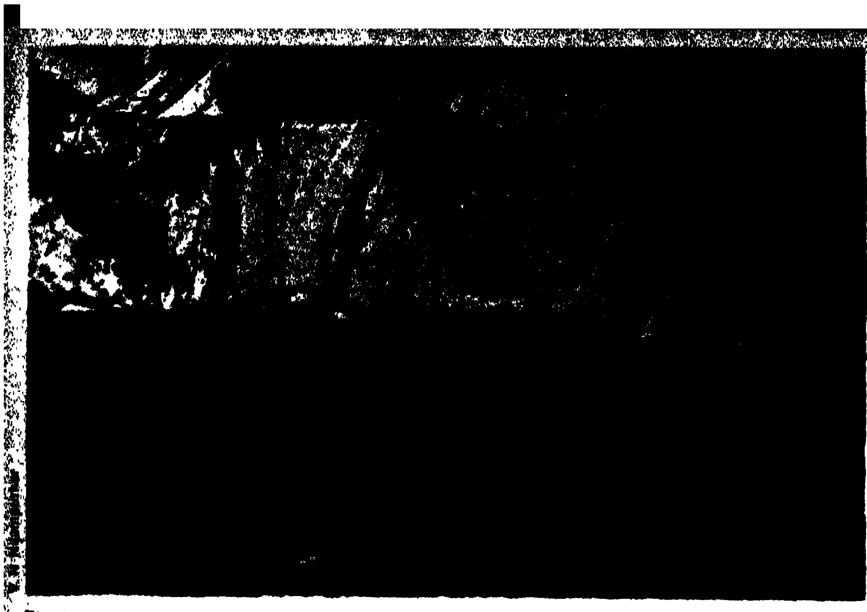


Fig.2 Melt water accumulates to form an en-glacial lake in the Changme-Khangpu glacier in Sikkim

crust are found in cold polar climates. In the polar glaciers, the temperature is below the freezing point even at considerable depths and even in summer there is practically no melting. In the temperate glaciers, the temperatures are not much below the melting point of ice, except in winter when the top layer may be frozen to a depth of tens of metres. The temperate glaciers produce copious runoff, and almost all the glaciers in Scandinavia, the Alps, the Americas and the Himalayas fall in this group.

Besides direct precipitation, in the Himalayas, avalanches also form an important source of snow deposition because of the steepness of the hills. Also, the Himalayan glaciers are at much higher altitudes compared to many others, such as Alpine glaciers, because the Himalayas, being at lower latitudes, are warmer. The perennial snow line (or equilibrium line) in the Indian Himalayas ranges from an altitude of about 4,300 metres in the west to 5,600 metres in the east, though this line may change from year to year even for individual glaciers.

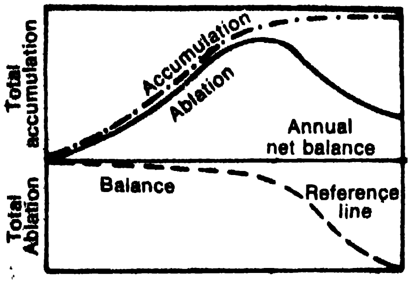


Fig.3 How a Himalayan glacier accumulates and loses ice with changing seasons

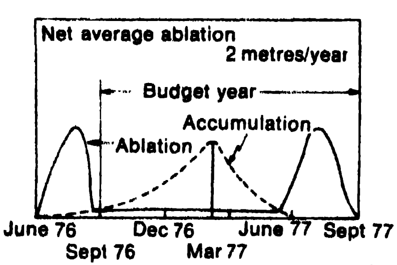


Fig.4 During 1977, the Nehnar glacier, Kashmir, shows a net ablation rate of 2 metres per year from its mass balance curve

Most of the Himalayan glaciers are only a few kilometres long, a few hundred metres wide,, about 10 metres thick at their snout, and up to a few hundred metres thick in the accumulation zone. There are exceptions, like the Zemu in Sikkim and the Gangotri in Himachal Pradesh (each about 26 km long), which are among the largest continental glaciers. And the Karakoram has even larger glaciers like the Siachen which is 72 km long.

Flow and mass balance

In spite of being solid, ice in the glaciers can flow because an ice crystal easily deforms and changes its structure. The steep slope and continuous accumulation in the accumulation zone, in addition to this structural change, keep the ice moving along. The surface ice of the glacier moves faster than ice at depth (Fig. 7). The path of ice within a glacier is complicated, but in general, ice is practically static near the snout, moves very slowly in the accumulation zone, picks up velocity downstream, and reaches its peak velocity near the equilibrium line. The velocity contours determined by continuous monitoring of some glaciers indicate that the speeds vary from a few metres a year to 100 metres a year.

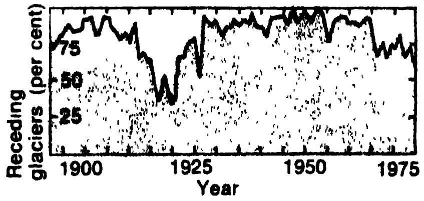


Fig.5 Per cent of receding glaciers in the Swiss Alps from 1890 to 1975. Figures compiled by Kässer and Allen

V N Nijampurkar

Fig. 6 A team from the Geological Survey of India carrying out a thermal drilling operation in the Nehnar Glacier, Kashmir. The tripod in the foreground aligns the corer

One conventional method for determining the flow rate and mass balance uses graduated long multicolour aluminium stakes buried about a metre deep in the glacier surface using a thermal or hand-operated drill and studies the movement of the stake in all the three directions with respect to a stable "reference" position. This method gives the mass balance and flow rates over short periods.

Several Himalayan glaciers have been studied using this technique, for example, the Nehnar in Kashmir, the Gara in Himachal Pradesh and the Changme-Khangpu in Sikkim. The studies found that most glaciers had a negative mass balance during the past decade,. that is , more ice is melting than the snow that is accumulating. That glaciers have been receding is also evident because several tributaries once connected

Table 3 [illegible]

[illegible]	Average [illegible] (metres)
[illegible]	56
[illegible]	10
1881-19 [illegible]	[illegible]

[illegible] values given here are based on the [illegible] piled by C.P. Vohra

with the main body of the glaciers are now disconnected—a consequence of the severe negative mass balance. If this trend continues, the consequences could be severe.

All glaciers, even those in the same basin, do not behave alike. While some advance, others in the same basin may retreat because the response times of individual glaciers are different. It is thus necessary to observe a large number of glaciers over a period to understand climatic changes. The limited data available from studies indicate that, fortunately, the trend of recession is reversing, at least for some glaciers, during the last couple of years, though only continued observations for years at different locations can tell us if this is a global trend.

Finally, the geologic evidence surrounding a glacier is equally important to understand its behaviour. The mapping, geology and geomorphology together then provide important parameters for dynamic models of glaciers.

Mathematical modelling

Mathematical models are a powerful tool in data analysis and interpretation as also for predicting the response of glacier systems. Vital to the reconstruction of climatic history is the link between the change in the glaciers' mass (annual balance) and in the local climate.

The different chronological records left by glaciers take the weather records far back in time. Moreover, because of the glaciers' large response time, it becomes possible to predict the future behaviour of glaciers, including the quantity of water available in the short and long run, if a climate-glacier model is available relating the behaviour of glaciers to meteorological variables.

The input parameters of such a model are provided by systematic data about the precipitation and ice temperatures, the advance or retreat of snout ice, the shrinkage or swelling of glacier size, the glacier's mass balance, and glacier flow rate—all collected over a long period.

Most of the mathematical models are based on a theory of kinematic waves which has been fruitfully applied to problems as different as flood waves in rivers and road traffic in big cities. J. F. Nye, of the University of Bristol, UK, has developed such a model based on some simplifying assumptions: (i) that the discharge depends on the distance from the snout, and the ice thickness, width and slope of the glacier, (ii) that the temperature of the glacier is uniform, (iii) that the ice has a

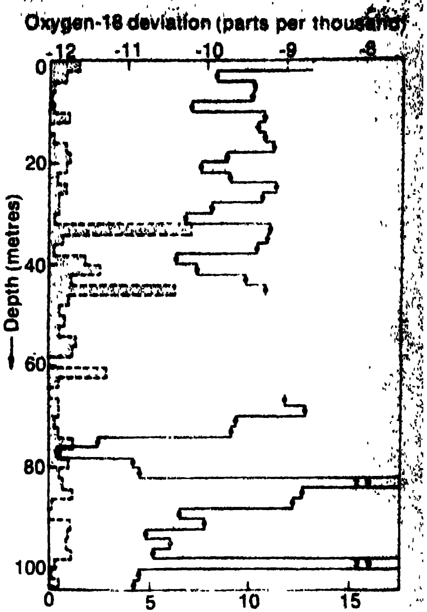


Fig. 9 Suspended dust (dotted line) and oxygen-18 deviation in the deep ice core of the Nehnar Glacier, Kashmir

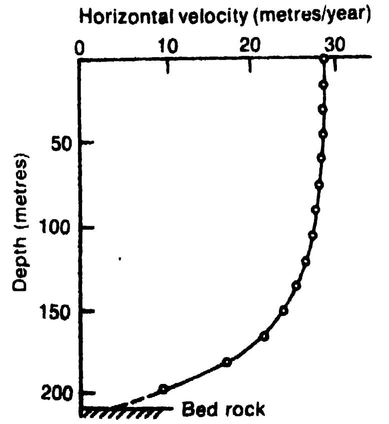


Fig.7 How horizontal velocity varies with depth in the Athabasca glacier, Canada

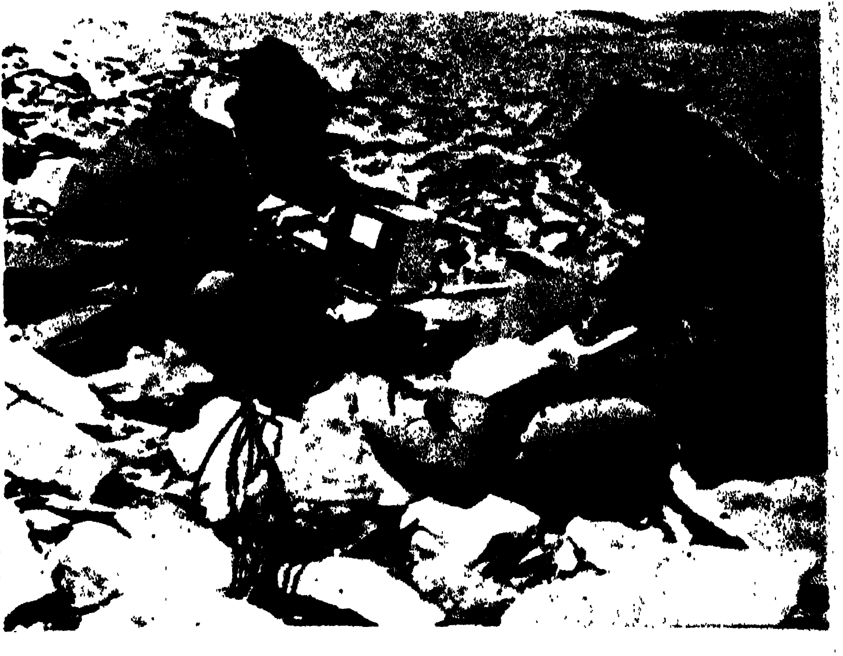


Fig.8 Measuring how temperature of ice changes as we go deeper is crucial in understanding the heat and mass balance of a glacier. Each cable of the electronic device in the temperature measuring arrangement shown has a thermocouple sensor that reaches to different depths below the glacier surface

uniform density, so that mass and volume are conserved, (iv) perturbation from the steady state is small, so that slow advance and retreat can be better studied, and (v) the perturbation in mass balance depends only on time.

Such models suggest that glacier mass balance is very sensitive to precipitation, temperature, albedo (surface reflectivity) and cloudiness. With a decrease in summer temperatures of even one degree Celsius, or an increase in the winter accumulation by ten per cent over a long period, glaciers would grow continuously. On the other hand, even a small amount of dust present will change its albedo by about two per cent leading to a considerable increase in melting. However, these models need to be improved by extending them to climate records several thousand years back using known glacier fluctuations.

Melting glaciers at will?

Since the melting of glaciers is sensitive to the albedo, attempts have been made to increase artificially the melting rate. Crude techniques such as spreading coal dust on the glacier surface have been attempted, with increased melting but with some pollution of the environment. In principle, of course, improved techniques of increasing water discharge in lean periods are possible.

One such possibility is sliding the glaciers down to lower altitudes by artificial surging where it will melt faster because of higher temperatures. This new idea, still untested, can only be adopted, however, after careful design and proper consideration of long term ecological effects.

Nevertheless, the techniques of controlling glacier discharge remain important. Even though we know so little about our glaciers today, they are an important water bank with a crucial role in harnessing our northern rivers. Not knowing about them is like not knowing one's bank balance.

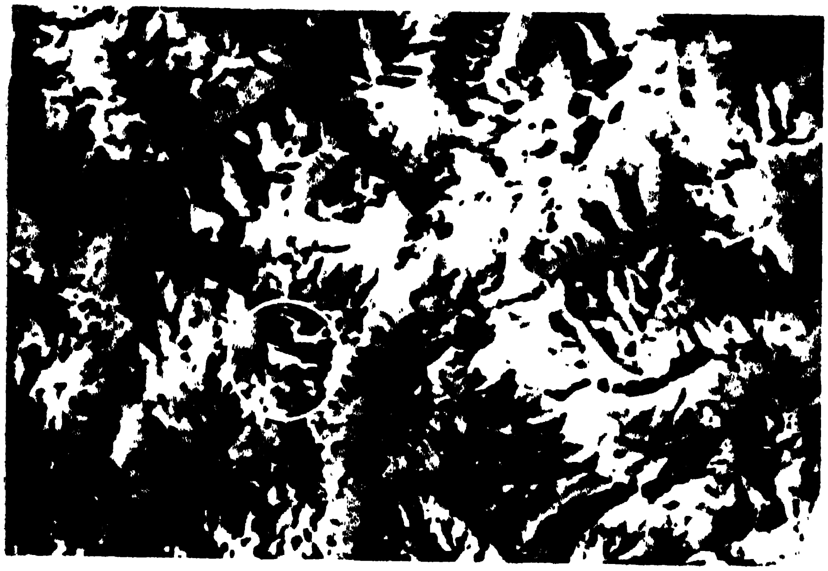


Fig. 10 Satellite view of the Nehnar glacier area. The glacier is circled

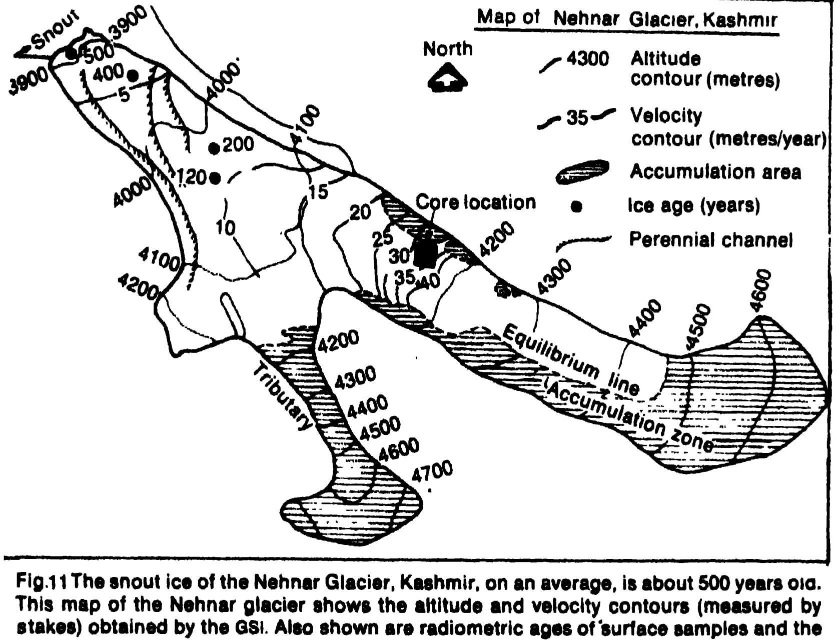


Fig.11 The snout ice of the Nehnar Glacier, Kashmir, on an average, is about 500 years old. This map of the Nehnar glacier shows the altitude and velocity contours (measured by stakes) obtained by the GSI. Also shown are radiometric ages of surface samples and the accumulation and ablation zones

Dr Bhandari is Professor at the Physical Research Laboratory, Ahmedabad, and the Chairman of its Hydrology Group. He specialises in applications of nuclear techniques in planetary physics, and has also worked on various aspects of atmospheric physics, hydrology and glaciology

Dr Nijampurkar is Senior Scientist in the Hydrology Group at the Physical Research Laboratory, Ahmedabad. He obtained his Ph D from Bombay University and specialises in applications of nuclear techniques in hydrology and glaciology. He has also participated in glacier expeditions to the Nehnar and Changme-Khangpu glaciers in the Himalayas and Mont Blanc in the Alps.

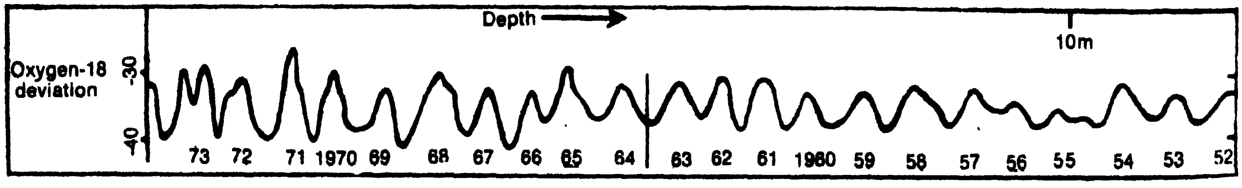
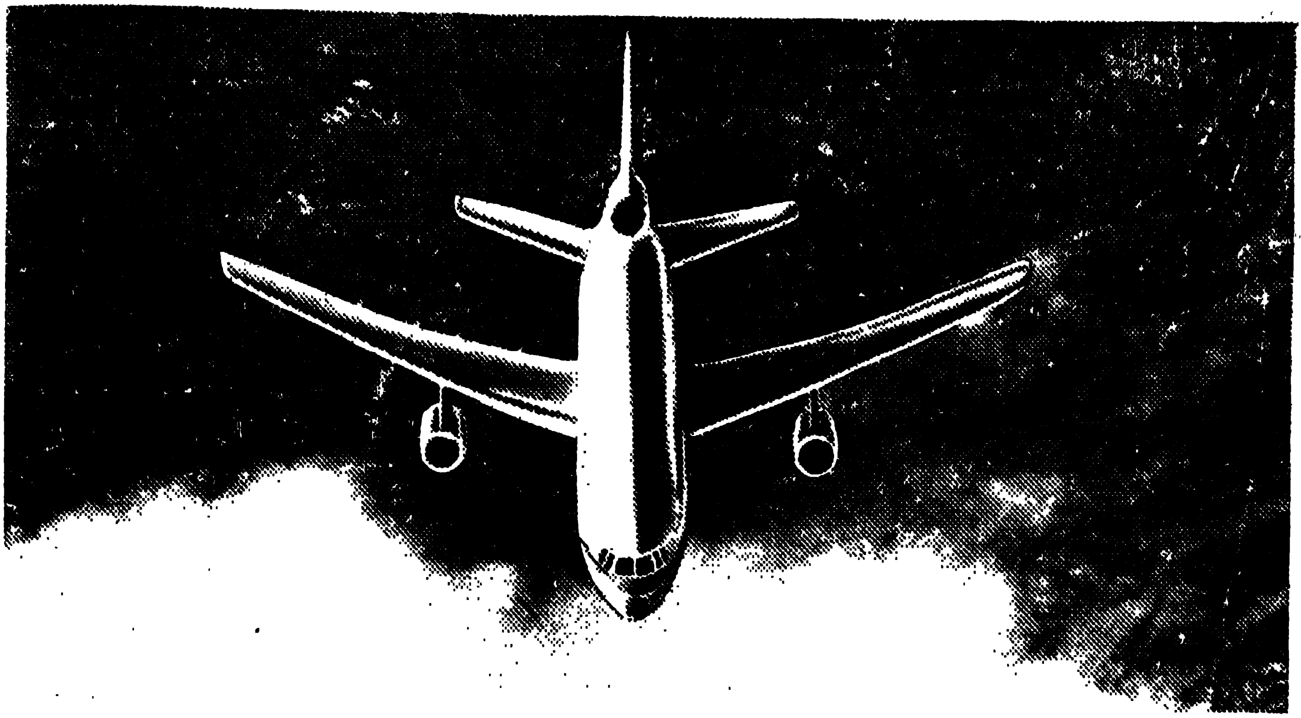


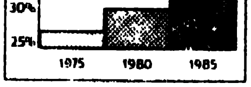
Fig. 12 Variation during summer and winter is clearly shown in an ice core from Greenland, by the data on oxygen -18 deviation through each annual layer (marked by the calendar year)



By 1985, this plane will be the most profitable for 32% of the sky.

The future of air travel.

The world is getting smaller. And airline routes are getting longer.



Long, thin routes (greater than 3,000 miles, carrying moderate passenger loads) totaled about 25% of air route mileage in 1975. By 1985, that number will be approximately 32%.

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Also, the L-1011-500 is uniquely equipped to land at some airports in weather bad enough to turn other big jetliners away.

The L-1011 offers something for passengers, too: supreme wide-cabin comfort.

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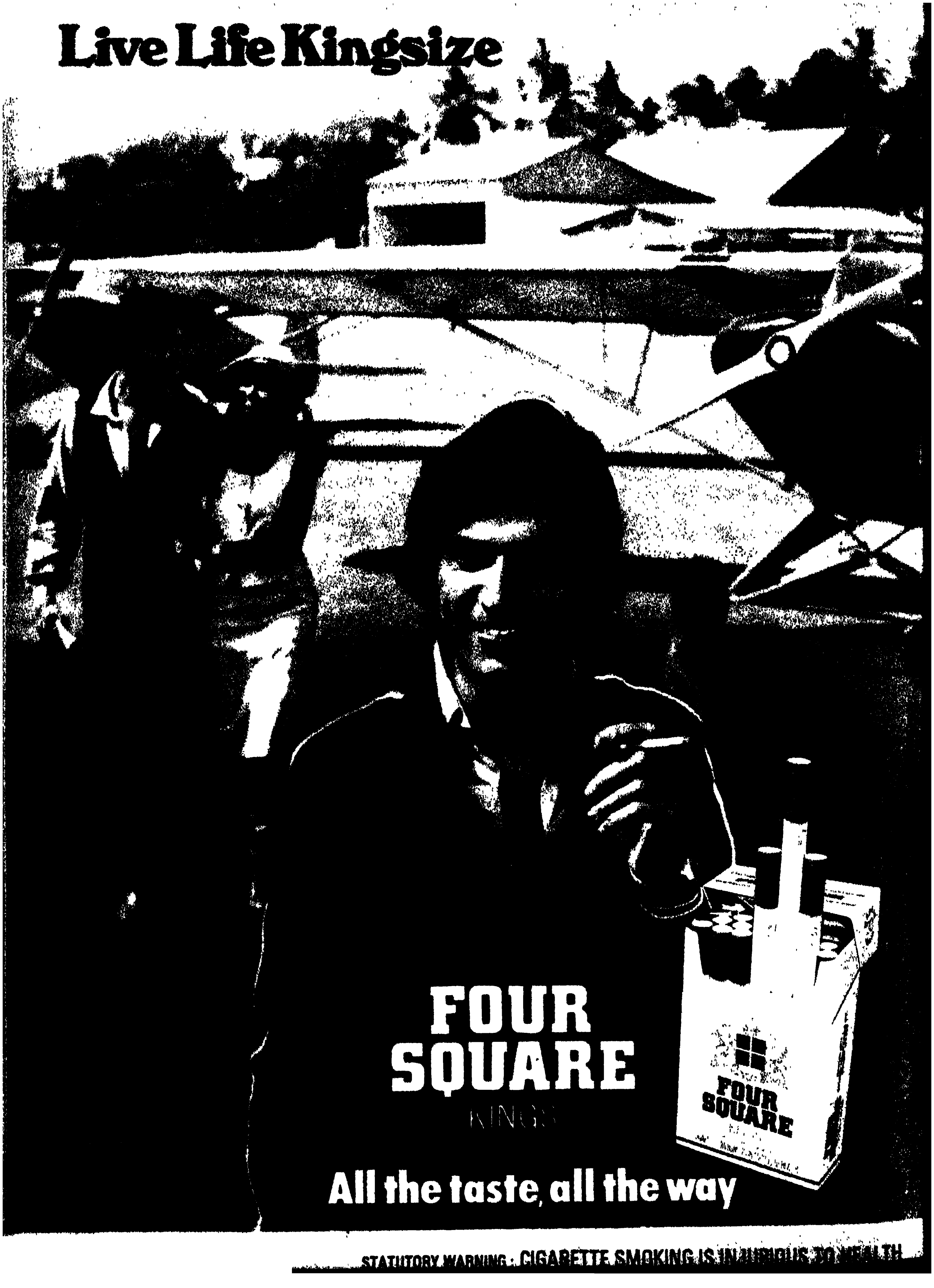
Take another look at the L-1011-500 TriStar.

Because 32% is a lot of sky.

Lockheed L-1011 TriStar



STATUTORY WARNING : CIGARETTE SMOKING IS INJURIOUS TO HEALTH

TELL US...

.. how do people entomb themselves?

RECENTLY, a swami, Satya Moorthe, buried himself in an underground pit in the house of a Bombay film actor for over six days without food or water. A select group of people witnessed the performance. Still considered a mystery, the trick can be explained scientifically. R. J. Vakil of Bombay was one of the earliest investigators who tried to explain the fundamental principle underlying the phenomenon. In 1950, he witnessed a demonstration staged by a yogi named Ramdasji, who stayed in a sealed concrete cubicle of 6,135 litres capacity for 62 hours. During the last six hours the chamber was filled with water.

Vakil opined that the volume of air locked up in the chamber was sufficient or the maintenance of the yogi's vital activities. He based his conclusion on J. B. S. Haldane's observation that the oxygen requirement of a man lying perfectly still is only 341 litres a day, or 14.2 litres an hour. As per Haldane's observation, the yogi needed only 880 litres of pure oxygen for his 62-hour sojourn underground. The pure oxygen came from 4,402 litres of air, assuming the normal atmospheric air to contain one-fifth of its volume as oxygen. The remaining capacity of the chamber, ,732 litres, was perhaps occupied by the body volume of the yogi, other equipment n the chamber, and water. However, Vakil made no attempt to measure the oxygen content in the air of the chamber and no verification of his theoretical ssumption was possible.

H. V. Gundurao and his associates were the next in line to investigate the phenomenon. They pursuaded a yogi to stay in a pit dug in their own laboratory. They also measured the oxygen and carbon dioxide content of the air in the pit. However, the pit was not airtight and so measurements were open to severe criticism.

Recently, B. K. Anand and his associates conducted some gruelling tests on one Ramanand Yogi of Andhra Pradesh, in their laboratory at the All-India Institute of Medical Sciences, New Delhi. Instead of the usual practice of digging a pit in the ground, they procured a tested airtight metallic-cum-glass box of about 2 x 1.3 x 1.3 metres, with a capacity of about 2,840 litres. Thus, the chances of air leaking out and/or getting absorbed in the soil of the pit were totally eliminated. Besides, it was possible to continuously see the subject's reactions and possible distress signs.

Ramanand Yogi remained in the box, for periods ranging from eight to 10 hours at a stretch. Many of his body functions were measured during this period. The air inside the box was analysed at regular intervals for its oxygen and carbon dioxide contents. One important observation that very nearly explains the mystery is that the metabolism and oxygen utilisation of the body is considerably reduced when carbon dioxide-rich air is inhaled or when the breath is held.

The yogi in this study had used 19.5 litres of oxygen per hour when he was lying perfectly still outside the box. But inside the box, he slowed down his breathing and held it for considerable lengths of time. The carbon dioxide content of the enclosed air in the box also rose. Consequently, his metabolic rate fell and was reduced by about 40 to 50 per cent. He used 10 to 13.3 litres of oxygen per hour

Normally about 2.5 per cent carbon dioxide is present in the expired air. Breathing five per cent carbon dioxide causes stress, and seven per cent makes it unbearable.

Holding the breath or breathing high concentrations of carbon dioxide increases the percentage of this gas in the blood and in various body tissues. Carbon dioxide being highly diffusible, rapidly penetrates the interior of the cell and interferes with its vital processes. It selectively affects the tissues of the nervous system and dulls many regulatory mechanisms. The temperature regulation is thrown out of gear and the body starts cooling, the circulatory centre is depressed and the heart starts slowing; the oxygen utilisation rate of most tissues gets depressed, resulting in profound reduction of the total body metabolism.

It would seem that any one, with the determination to stay in a closed space, can do so and live inside an underground pit for some hours without special previous preparations. This was neatly proved in an experiment staged at Yogashram, Lonavala, near Bombay, by P. Karambelkar and two of his associates.

The investigators motivated two volunteers who had no practice of any kind of respiratory or yogic exercise, to act as controls for their study on human subjects staying in an airtight pit. The volunteers had no difficulty in staying in an oil-sealed underground cement-concrete pit for 12 to 18 hours at a stretch. They breathed the same air they exhaled in the closed space during their confinement and reductions in their heart rate, respiratory frequencies and consumption of oxygen were observed.

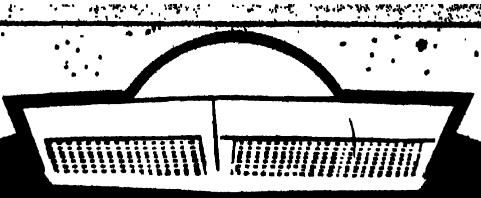
However, staying for long periods in narrow closed chambers without food, water and proper previous preparations is not possible. Persons who entomb themselves for days together have generally a long practice of yoga-type breathing and yoga exercises. These practices increase the tolerance to carbon dioxide. Such people can withstand longer and higher (7.73 per cent) concentrations of carbon dioxide in the inspired air.

Swami Satya Moorthe at the start of his 160-hour ordeal

Yogic practices also bring about a conditioning of the limbic system in the brain, which is responsible for regulating the visceral functions of the body. Thus, those who live for long periods in underground cells have by repeated practice learnt to control the higher autonomic centres that regulate the involuntary functions and the various metabolic activities. Also, the various feats of control over organs and body functions exhibited by yogis are achievements naturally acquired by the body and have nothing supernatural about them.

SHANKER RAO

Dr. Rao was formerly Professor of Physiology, Gandhi Medical College Hyderabad.



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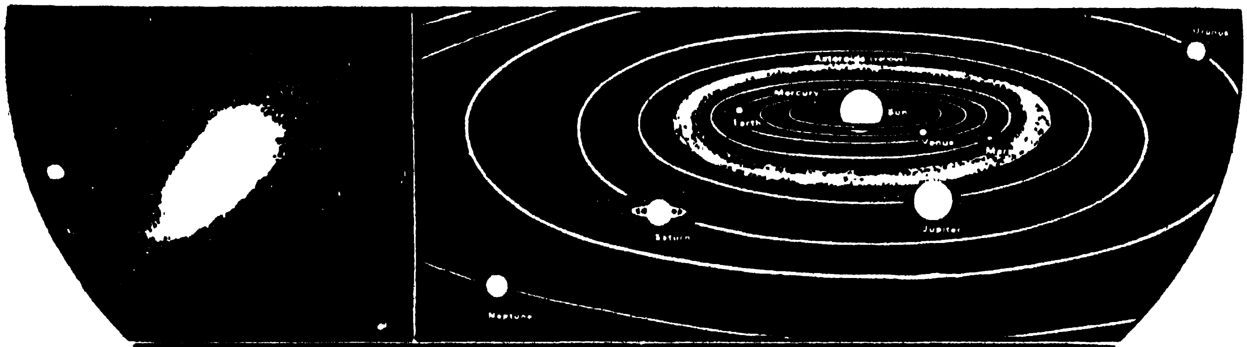

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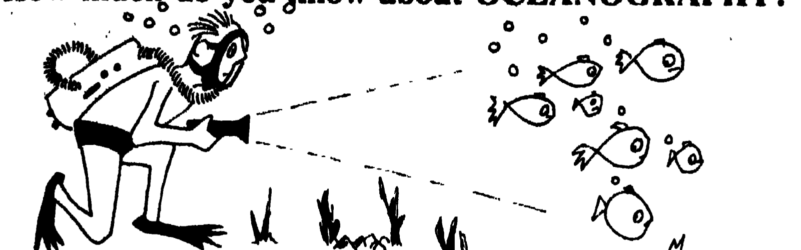
How much do you know about OCEANOGRAPHY?



Oceanography deals with the scientific study and exploration of the oceans in all their aspects. Here, we touch only certain aspects of the oceans and their exploration, leaving out its life forms, which we shall touch in a future quiz. Answers to the 10 questions are given overleaf.

1. When a layman conceives of the salinity of sea water, he thinks of its "saltiness". An oceanographer would define "salinity" as:
A. The total weight of dissolved material in one kilogram of sea water.
B. The total volume of dissolved sodium chloride in 10 kilograms of sea water
C. The total volume of dissolved material in one volume of sea water.

2. The "residence time" (or the time that would be required for the rivers to add to the oceans a mass of water equal to the water content) of the oceans is:
A. 22 years.
B. 44,000 years.
C. 1,000 years.

3. A Ghyben-Herzberg lens is:
A. A body of fresh water overlying salt water below a barrier beach.
B. A special wide-angle lens used for underwater cameras.
C. A special zoom lens used for underwater cameras.

4. The "Moho" is:
A. An acronym meaning Mobile Observation Habitat Obnubilation.
B. The boundary between the Earth's crust and mantle.
C. An imaginary line touching the deepest ocean depths.

5. The first mobile deep diving vehicle was:
A. Bathybius.
B. Bathyscaphe.
C. Bathysphere.

6. The contribution of "Mr. Unumo" and "Mr. Mobot" was towards:
A. Undersea oilpipe operations.
B. Seismic refraction shooting.
C. Theory of plate tectonics.

7. The acronym SCUBA stands for:
A. Sea Centre Underwater Bathing Apparatus.
B. Self contained Underwater Breathing Apparatus.
C. Single Chord Utility Breathing Apparatus.

8. The oil-bearing Bombay High structure is:
A. Diapiric.
B. Sympatric.
C. Halocline.

9. The following persons have designed well-known devices commonly used in oceanography (and named after them). Match the names on the left with the devices on the right (A, B, C and D stand for the names.)

A. C. Hardy
Fridtjof Nansen
J. C. Swallow
Van Ween

A bottle
B continuous plankton recorder
C grab
D float

10. The abbreviation MHWS stands for:
A. Mean High Water Springs.
B. Man-made Hot Water Springs.
C. Marine Hot Water Springs.

MEDICAL ENTRANCE

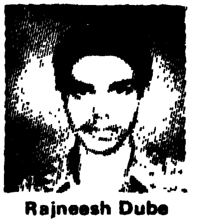
OUR 1 TOPPERS 1981

Atul Bedi
1st in C.M.C., Vellore,
Selected in A.I.I.M S. Delhi, JIPMER, Pondicherry, CMC, Ludhiana, Medical College, Calcutta, I.M.S., Banaras.

Preeti Aggarwal
1st in P M T Panjab
2nd in Pre Medical Panjab,
12th in Medical Entrance Delhi, (4th among girls).

Sandeep Khurana
1st in Pre-Medical Panjab, 2nd in C M C, Ludhiana
4th in P M.T. Panjab,
11th in Medical Entrance Delhi

Anita Deswal
1st in B.J. Medical College, Pune.
3rd in A F M C.
7th in Medical Entrance, Delhi
14th in JIPMER Pondicherry.


Rajneesh Dube
1st in A.F.M.C. Pune. (Poona)
2nd in C.P.M.T. (U.P.)
7th in I.M S., BHU, Varanasi.

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29-T, PATEL NAGAR, NEW DELHI-110008 ● 32-T, NEHRU PLACE, NEW DELHI-110019.

The Answers

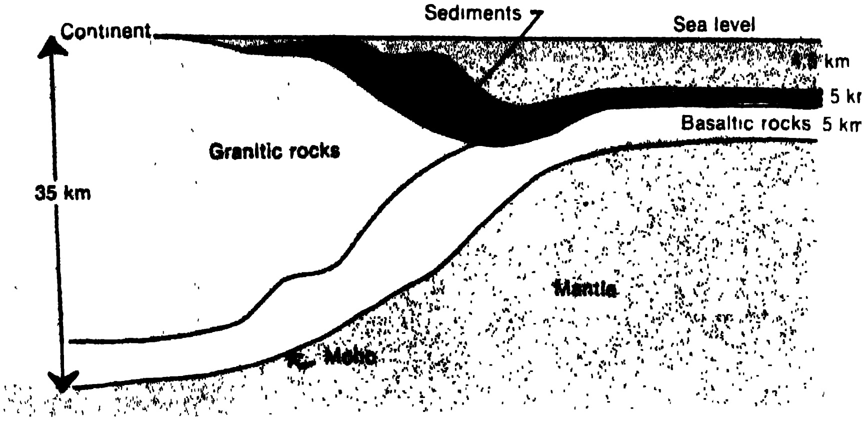
1.—A: Salinity is defined as the total amount of dissolved material, in parts per thousand by weight in one kilogram of sea water when all the bromine and iodine have been replaced by the equivalent amount of chlorine, all the carbonate has been converted to oxide, and all the organic matter has been oxidised.

The average salinity of oceanic water is 35 parts per thousand. Normally the chlorinity of sea water is determined (this is 19.377 parts per thousand in standard sea water), and the salinity then calculated as S = 1.8066 Cl.

2.—B: The oceans of the world contain 1.4 x 10^{21} kilograms of sea water and the world's rivers add water to it at a rate of 10^{9} kilograms per second. Thus it would take 1.4 × 10^{12} seconds (or 44,000 years) for the rivers to add to the oceans a mass of water equal to the water content of the oceans. The residence time of the total salts in the oceans is 22 years.

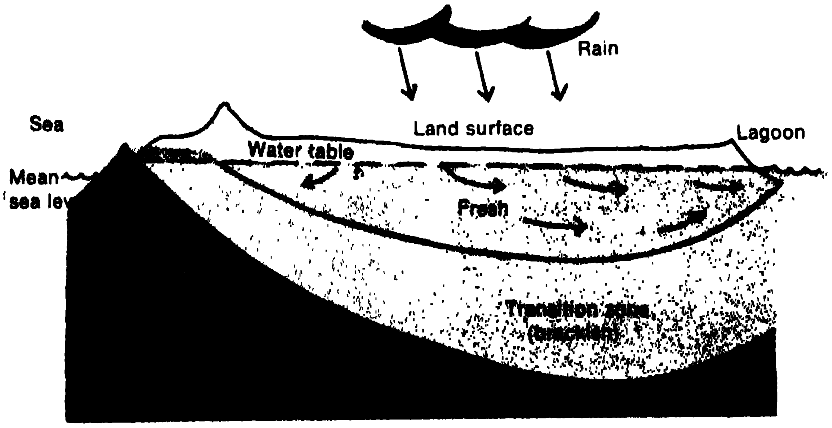
3.—A: A Ghyben-Herzberg lens is named after the two scientists who discovered the mathematical relationship between the height of the water table above sea level and the depth of the fresh water layer.

4.—B: Abbreviated from "Mohorovicic discontinuity", after the Balkan seismologist A. Mohorovicic, it occurs at a depth 35 kilometres below the continents, but only 11 kilometres below the ocean surface.



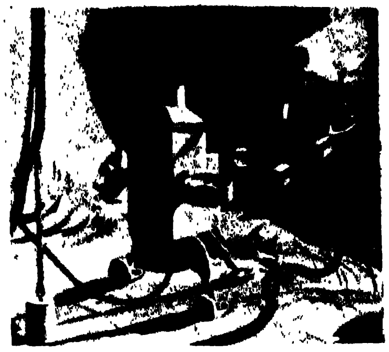
Moho, and the granite-basalt configuration

5.—B: Designed by the Swiss scientist Auguste Piccard, Bathyscaphe is akin to an underwater balloon in which petrol keeps it afloat, water is pumped into ballast tanks to make it sink, and iron pellets released to bring it back to the sea surface. Its horizontal movement, using battery-operated propellers, is however very slow.

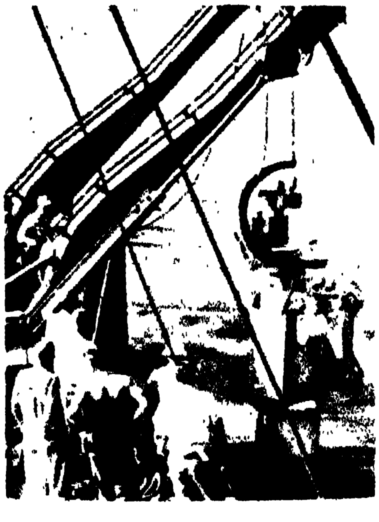


Freshwater lens configuration on a barrier beach

6.—A: The two are names of robots used for undersea oil pipe operations. Mr. Mobot (for mobile automation) is 4.3 metres tall, with a television camera for eyes and a sonar pinger and hydrophone for ears. It can move forward by means of two propellers, and a variety of tools can be bolted on to its arms. Mr. Unumo (universal underwater mobot) is a more versatile device with tripod feet, flexible arms and hand-like appendages.



Mr Unumo



Mr. Mobot

7.—B: The Self Contained Underwater Breathing Apparatus (SCUBA) is now popularly known also as "aqualung"

8.—A: Diapiric structures are formed by the slow upward plastic migration of relatively lighter sediments through several kilometres of denser overburden and may project up to several hundred metres above the sea floor. Examples are salt domes — oil is usually found associated with them. Hence the word "high" in Bombay High

9.—A: Nansen bottle; B Hardy's continuous plankton recorder; C Van Ween grab; D Swallow float

The Nansen bottle is a metal tube, open at both ends, that is clamped on to a thin wire. When it is lowered to the desired depth, a cylindrical weight called the "hydrographic messenger" is slid down the wire. As this hits a trigger on the bottle, the bottle turns through 180 and the two ends close by spring-loaded valves, thus enclosing about 1.2 litres of water sample.

Nansen bottle being immersed

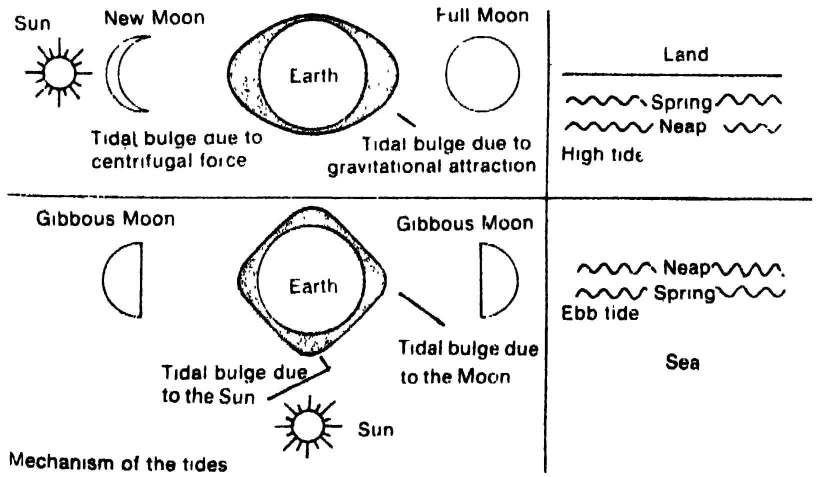
Hardy's continuous plankton recorder (in contrast to the slow-moving, conical plankton net) can be towed behind a fast moving ship. As the device moves forward, plankters entering the orifice on its nose are sandwiched between two strips of gauze wound by means of a propeller into a tank containing preservative fluid.

The Van Ween grab is used for quantitative sampling of life at the sea bottom. Two heavy, semi-cylindrical "jaws" are held open by long steel arms. When the grab hits the bottom, a locking notch disengages the arms, and the jaws shut, enclosing a known volume of bottom sediment.

The Swallow float is a sealed aluminium tube with a built-in acoustic transmitter that can be thrown into the sea. Since it is less compressible than sea water, it will sink until the pressure is such that the water density makes it neutrally buoyant. It will then drift with the current. The "ping" received into a hydrophone on the ship can be followed for several weeks.

10.—A: Mean High Water Springs. High water is another term for "high tide" (as opposed to ebb tide or low water). When the Sun, Moon and Earth are positioned on one line (in conjunction), the combined gravitational attraction and centrifugal force are very strong. So high tides are very high and ebb tides very low. These are known as spring tides and they occur at or around full and new moon. When the Sun, Earth and Moon form a right angle to each other, the gravitational and centrifugal forces are weaker, and the tides are not so strong; these are called neap tides. The 'mean" is the average of many spring tides.

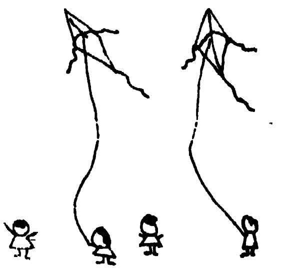
This quiz was prepared by
Dr. B. F. CHHAPGAR who is Scientific Officer for aquatic radioactivity studies at BARC, Bombay.


Sun
New Moon
Earth
Full Moon
Tidal bulge due to centrifugal force
Tidal bulge due to gravitational attraction
Land
Spring
Neap
High tide
Gibbous Moon
Earth
Gibbous Moon
Neap
Spring
Ebb tide
Tidal bulge due to the Sun
Tidal bulge due to the Moon
Sea
Sun

Mechanism of the tides

Highlights of next month

How does a kite fly?



How forests affect climate

The dizzy world of particles and nuclei

Interview with Francis Crick

Deciphering proto-Indian scripts

SCIENCE TODAY
January 1982

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②
③
④
I wish I could make an amplifier like Aman did!
⑤
Now Dad, following in my footsteps, is making a TV Set from a Jetking Kit for Mummy!.... With my help, Ofcourse!
⑥
But how do you do it, Aman?
Wow! I must send for a Jetking Kit today!
It's easy! Just follow Jetking's simple manual! That's all!
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YOU TOO CAN DO IT

Automatic staircase light

THIS is a very useful and simple solid-state device for all houses. If it is dark and you just press one of the push buttons, all the staircase lights light up. They remain lit for about three minutes and then automatically go off. If there is sufficient light, then the lights do not come on at all.

You will notice that the device is the simplified version of the "Automatic porch light" (SCIENCE TODAY, December 1978).

The circuit of the device is fully solid-state and uses a single integrated circuit, IC 555, and a few other components. The IC 555 is used in the device as a monostable multivibrator; its action here is better understood from the functional block diagram of the IC 555.

The IC is divided into blocks representing the upper and lower comparators A and B, the control flip-flop F, the inverting output stage D and the discharging transistor Q 14.

In the standby state, that is, when no trigger pulse is applied to the trigger terminal No. 2, the control flip-flop provides a 'high' output which holds the discharging transistor in the conducting state, which clamps the charging capacitor C to the ground level. The flip-flop also drives the inverting amplifier to provide 'Low' output. The internal voltage divider, comprising three 5 K ohms resistors in series, provides ⅔ Vcc and ⅓ Vcc to the upper and lower comparators, respectively. These two voltage levels thus determine the threshold and trigger levels of the two comparators.

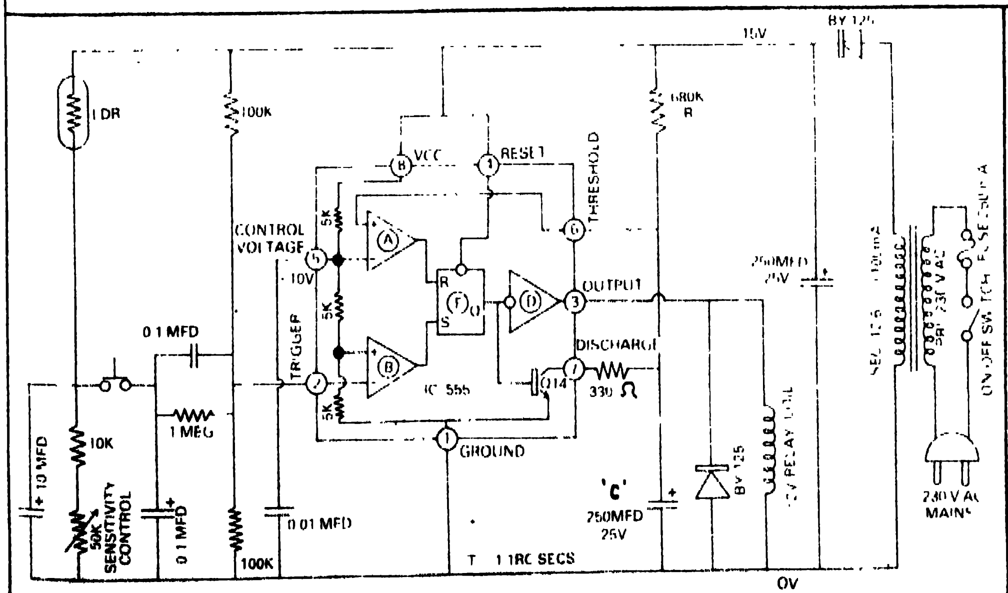
The LDR along with the series network of resistor and potentiometer acts as a voltage divider. During the daytime, when sufficient light falls on the LDR, the increase in the conduction of the LDR provides sufficiently high voltage across the series network of resistors and potentiometer. If there is not sufficient light, the drop in the conduction of the LDR causes the voltage across the series network to drop proportionately. The 10 mfd capacitor across the series network is for smoothening out the electrical voltage developed across it. The setting on the sensitivity control potentiometer will determine the intensity of light at which the series network will provide just sufficient voltage to drive the trigger terminal of the IC, through the 0.1 mfd capacitor and the push button, to ⅓ Vcc level.

Whenever there is insufficient light and the push button is pressed, the trigger terminal which is held at ½ Vcc level by the two 100 K resistors, gets the necessary negative-going pulse through the 0.1 mfd capacitor—sufficient to make the trigger terminal less positive than ⅓ Vcc level. This causes the lower comparator to provide the output which changes the state of the control flip-flop from high to low. The control flip-flop thus cannot hold the discharging transistor and the inverting output stage provides high output at terminal No. 3 of the IC. This drives the relay coil As the timing capacitor C, 250 mfd, is now unclamped, it starts charging through the 680 K resistor. When the capacitor charges to ⅔ Vcc, which is the threshold of the upper comparator, it resets the flip-flop back to the normal high state. The flip-flop thus simultaneously discharges the timing capacitor C through the 330 ohms current-limiting resistor and the discharging transistor Q 14, and brings the output again to the low level, which switches off the relay. This completes one cycle of monostable operation.

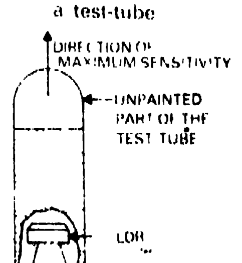
The 12V DC relay used in the device is directly operated by the output terminal of the IC 555. To restrict the relay driving current, the resistance of the relay coil should be 150 ohms or more. Though the circuit shows only one push button, you can have any number of push buttons in parallel. This will enable you to operate the device from any floor. In the same way, you can also have any number of lamps, operated by the relay contact of the device, provided you do not exceed the rated capacity of the relay contact.

The timing capacitor C has two different paths for charging and discharging. The values of the timing capacitor, that is, 250 mfd, and the resistor in the charging path, that is 680 K ohms, are so selected that the capacitor takes about three minutes to charge to 2/3 Vcc level. The selection of the current limiting resistor (330 ohms) should be such that it should limit the discharging current passing through the discharging transistor Q 14 without appreciably increasing the discharging time (which is typically a fraction of a second); so that the unit is immediately ready for the next operation.

The LDR can easily be fitted inside a test-tube as shown in the figure. The rubber cork at the bottom of the test-tube should have an aperture to take the two leads connecting the LDR The test-tube should be painted with any waterproof black paint, leaving about 25 mm from its top up to the rubber cork. The wires connecting the LDR and the electronic unit should preferably be continuous, as most

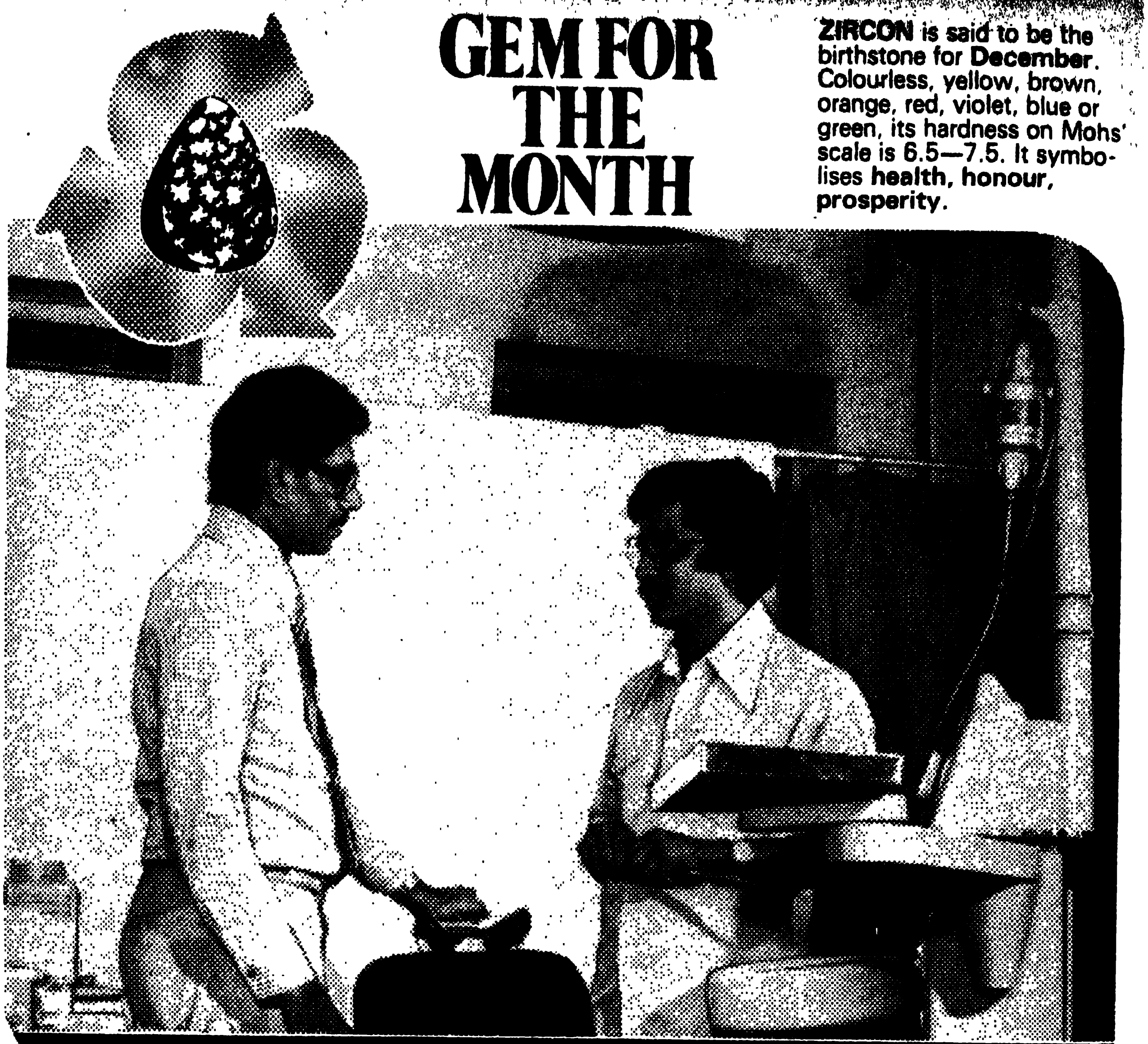


Light dependent resistor (LDR) fitted inside a test-tube


DIRECTION OF MAXIMUM SENSITIVITY
UNPAINTED PART OF THE TEST TUBE
LDR
RUBBER CORK

GEM FOR THE MONTH

ZIRCON is said to be the birthstone for **December**. Colourless, yellow, brown, orange, red, violet, blue or green, its hardness on Mohs' scale is 6.5—7.5. It symbolises **health, honour, prosperity.**



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of this wiring will remain outside the house. The unpainted top part of the test-tube will allow the light to come in. The painted part will obstruct the entry of light from the sides.

The LDR unit should be fixed in a suitable place outside the house, pointing towards the sky in such a way that the LDR will receive the maximum natural light. It should never be fixed vertically or at an angle which will allow the direct light from the sun to reach the LDR.

You will need:

Semiconductors: IC 555—1 No.; LDR—1 No.; Diodes BY 125—2 Nos.

Resistors (all ½ watt): 1 Meg—1 No.; 680 K—1 No.; 100 K—2 Nos.; 10 K—1 No.; and 330 ohms—1 No.

Potentiometer: 50K carbon linear or wire-wound—1 No.

Capacitors. Electrolytic: 250 mfd, 25V—2 Nos.; 10 mfd, 25V—1 No.; Ceramic or Polyester: 0.1 mfd—2 Nos.; 0.01 mfd—1 No.

Relay: 12V DC with coil resistance more than 150 ohms and at least one set of changeover contact,—1 No.

Approximate cost of the above electronic components in the Bombay market, Rs. 90.

Transformer: Pri: 230V AC. Sec: 12.6V @ 100 mA.

Misc.: IC experimenter's vero board, 250 mA fuse with holder, normally open pushbutton switches, solder, wires, screws, suitable enclosure, etc.

ANIL V. BORKAR

BRAIN TEASERS

Long wait:

ONCE I reached a railway station very early. The staff had their own way of indicating the train timing, for example, after 11 a m they used 12, 13, 14, etc (without "a m" or "p m"). In the ample waiting time, I found that if I divided the departure time (in whole number of hours) by the sum of its digits, I got a quotient of 4 and a remainder of 3. What was the departure time (in whole hours)?

V. A. SHENAI

(Solution next month)

Solution to last month's Brain Teaser

Six statements

Observe that every statement in the given set contradicts all the remaining statements, and hence only one can be correct. If we assume the first as correct, it means that five statements are correct, which is not possible. So the first statement is not correct. Similarly, the second, third and fourth statements also cannot be correct, for, if they are assumed to be correct, it will mean that the fourth, third and second statements, respectively, are correct. If the sixth is assumed as correct, it means that this statement also is wrong—which is a contradiction. Hence, the sixth also cannot be correct. That leaves the fifth statement. If this is assumed to be correct it means that only one of the six statements is correct, that is, the fifth itself. This results in no contradiction.

Hence, only the fifth statement can be correct.

MEETINGS CALENDAR

January

Crystal lattice defects and defect interactions, symposium, Department of Metallurgy, BHU, Varanasi (Dr B D Sharma, Convenor, Crystal Lattice Defects and Defect Interactions, Metallurgy Division, BARC Bombay 400 085). (Dates not intimated)

(2 days): Monte Carlo Methods, workshop, BARC Bombay (S R. Dwivedi, Convenor, Workshop on Monte Carlo Methods, Theoretical Reactor Physics Section, 5th floor, Central Complex, BARC, Bombay 400 085). (Dates not intimated)

11-16: System analysis and its application to engineering problems, regional workshop, Bombay (B.Raj Bhandari, UNESCO House, 17, Jor Bagh, New Delhi-110 003)

11-12: Value analysis and engineering, seminar, Bangalore (Regional Director, NPC, No. 11, Lady Curzon Road, Bangalore 560 001)

18-26: Solar science and technology and solar energy convention, int. symposium, Indian Institute of Science, Bangalore (Prof.M. Ramakrishna Rao, Regional Instrumentation Centre, Indian Institute of Science, Bangalore 560 012)

19-22: Structured analysis and design, workshop, Madras (Prof H.N.Mahabala, Computer Centre, Indian Institute of Technology, Guindy, Madras 600 036)

20-22: EDINFO, int. symposium on education informatics, Madras (T. V. Natarajan, Chairman, Organising Committee, Computronics, India, 11, Kasturi Ranga 2nd Street, Madras 600 018)

22-23: Maintenance systems for power plants, seminar, Bangalore (Regional Director, NPC No. 11, Lady Curzon Road, Bangalore 560 001).

22-25: Computer manpower development (CST-82), VII annual convention of the Computer Society of India, Adyar Gate Hotel, Madras (Prof H.N.Mahabala, Computer Centre, Indian Institute of Technology, Guindy, Madras 600 036)

26-27: Refrigeration of perishable products for distant markets International Institute of Refrigeration conf., Waikato University, Hamilton, New Zealand (Royal Society of New Zealand, P.O Box 12.249 Wellington, New Zealand)

28-30: High temperature chemistry, symposium, BARC Bombay (M. S Chandrasekharaiah, Convenor, High Temperature Chemistry Symposium, Chemistry Division, Bhabha Atomic Research Centre, Bombay 400 005)

February

Non-isotopic immunoassays and their applications, int. symposium-cum—workshop, New Delhi (Prof G P Talwar, Dept. of Biochemistry, All India Institute of Medical Sciences Ansari Nagar, New Delhi 110 024) (Dates not intimated)

Soil science, int. conference, Vigyan Bhavan, New Delhi (Dr J. S. Kanwar, Director for Research, International Crops Research Institute for the Semi-Arid Tropics, ICRISAT, Patancheru, P.O 502325, A.P). (Dates not intimated)

1-7: Space sciences, symposium, Indian Institute of Science, Bangalore (Prof R.R. Daniel, Tata Institute of Fundamental Research Bombay 400 005)

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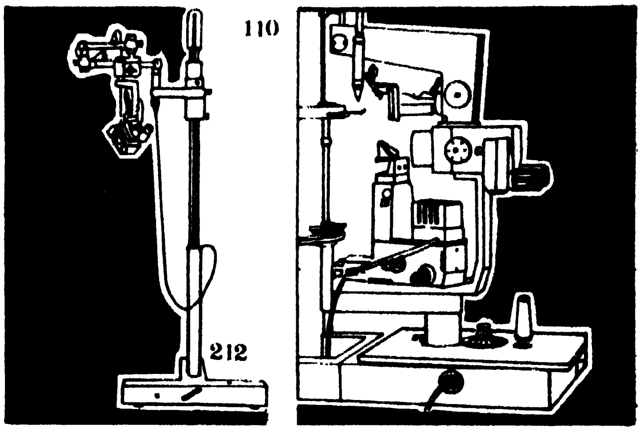

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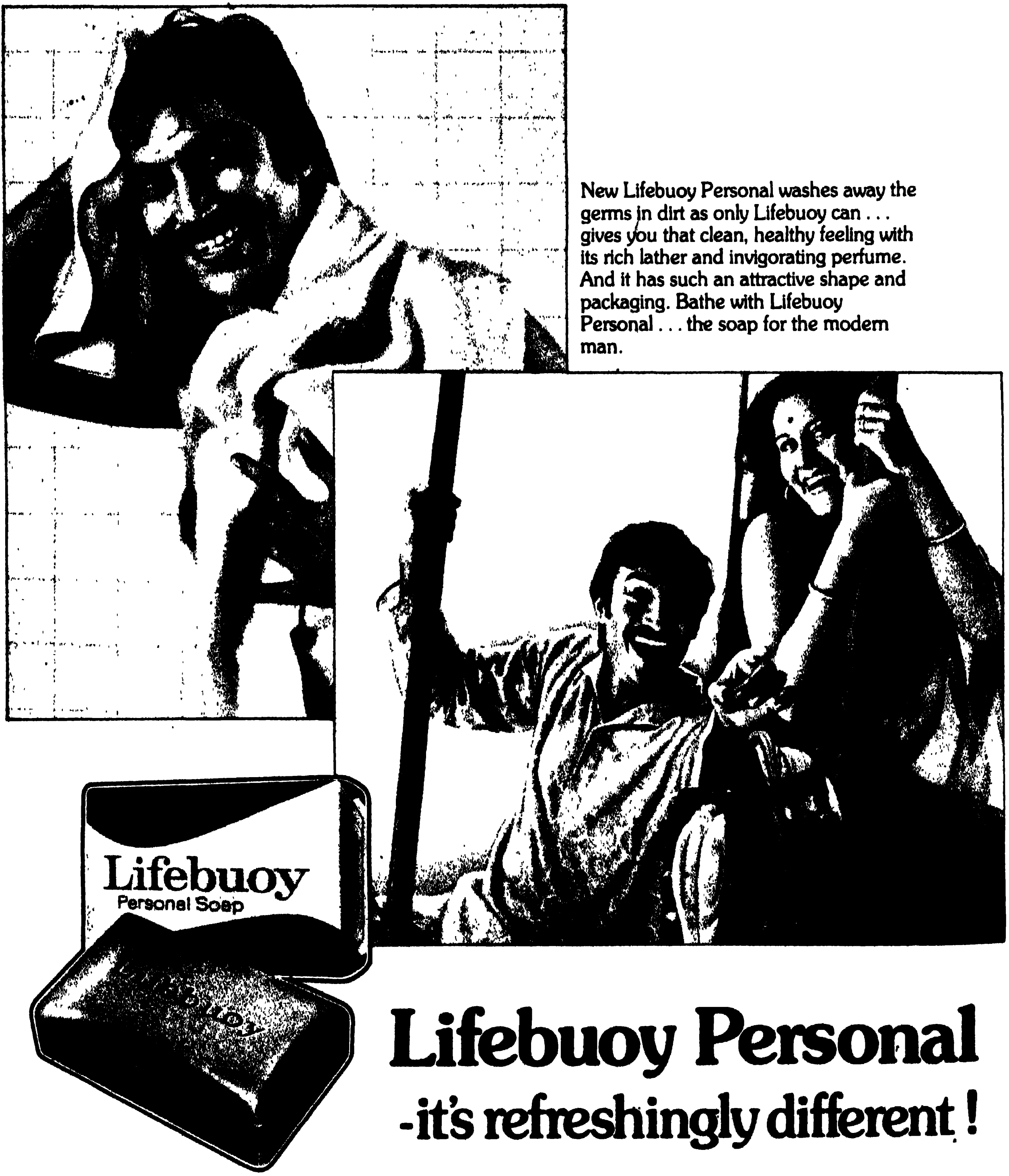

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IF...

...there were no chlorophyll molecules

THE only inexhaustible reservoir of energy available for life forms on the Earth is the electromagnetic radiation from the Sun. Chlorophylls, those green plant pigments, are the most remarkable natural pigments, which harvest the solar energy and convert it to storable chemical energy through photosynthesis.

A unique achievement of evolution has been to provide organisms with chlorophylls. Without them, life on the Earth would have been restricted to rare spots, such as volcanic springs, where free energy is available through chemical oxidation. But for chlorophylls, the Earth would have been left with primitive life forms, presenting a totally different scenario from the present day world.

The drama of photosynthesis consists of two main acts. The first is played on a lighted stage and carries out water oxidation and produces energy-rich adenosine triphosphate (ATP) molecules, paving the way for the second act. This is said to be staged on a darkened stage, as it requires no light. Carbon dioxide molecules are reduced to carbohydrates by drawing upon the energy and reductant generated in the earlier process. Chlorophylls play a central role and link the inputs and outputs of photosynthesis. However, only one per cent of solar radiation is intercepted by green plants and of which only ten per cent is utilised in the production of organic compounds. Hence, only 0 1 per cent of solar energy is sustaining life on this planet through chlorophylls.

The evolutionary development of photosynthesis is indeed remarkable because, besides the complex organic pigments, the chlorophylls, a number of enzymes, not known to be synthesised outside the living organisms are also required. The early chemosynthetic organisms which used energy from chemical reactions have not only incorporated accidentally-formed chlorophyll molecules, but these organisms also discovered that the chlorophylls can be used for capturing the light energy required for the synthesis of carbon compounds. It is very likely that biological evolution would have stopped at the chemosynthetic stage on many planets due to lack of chlorophyll molecules. On such planets, life forms would be dependent on a chemically unstable environment. And, if it is true that all atmospheric oxygen on the Earth is photosynthetically generated, then pre-photosynthetic life must have depended on some unstable chemical systems not containing free oxygen. Such systems are rare on the Earth and confined only to photosynthetic bacteria.

It is very likely that the photochemical production of energy (ATP) through photophosphorylation developed before the photo-chemical production of reduced carbon compounds from carbon dioxide, as the latter requires the operations of two photosystems, as against one by the former. The abundance of precursor molecules such as acetate and formate in the primitive oceans must have enabled the synthesis of glucose, utilising ATP molecules produced through photophosphorylation. The abundant supplies of organic material from primitive oceans could have been used by the then existing organisms capable of only photophosphorylation but not photoreduction of carbon dioxide. But an organism only capable of photoreduction would require large quantities of ATP generated from an inorganic source. Hence the former type of organisms must have evolved earlier than the latter.

Presumably, another significant mutation must have occurred as the availability of organic compounds became scarce. These are the oxygen-evolving blue-green and green algae and higher plants, capable of using the practically unlimited supply of water as a source of hydrogen. So, the atmosphere became oxygenic, leading to the evolution of new type of organisms which require free oxygen for respiration. The crucial role played by chlorophylls in steering the course of evolution could hardly be over-emphasised and it is bewildering to imagine the state of affairs on our planet if chlorophylls were not there.

There are relatively few biological molecular structures, with the exception of phytochromes, that can absorb visible light. Chlorophylls have absorption in the red and blue regions of the visible spectrum. And, in this region of the spectrum sunlight is most abundant. Maybe, this is one of the reasons why chlorophylls have been selected by nature as the main pigment in photosynthesis. The absorption of photons in the blue and red regions of the spectrum by the chlorophylls is associated with the excitation of specific electrons of the molecule to excited states which undergo specific chemical reactions by donating electrons to the photosynthetic electron transport chain. This provides the basis for photosynthesis.

Additional reasons for the choice of chlorophylls are the specific physicochemical properties that bind chlorophyll in appropriate locations in the cell and its capacity to serve as an effective photocatalysts.

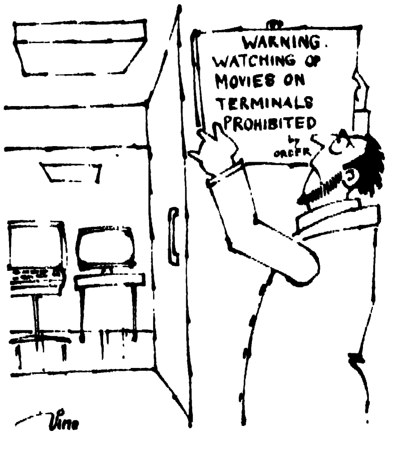
Chlorophyll molecules play a formidable task in maintaining atmospheric oxygen and carbon dioxide concentrations at constant levels. Annually, 13×10^{10} tons of oxygen is produced by the activity of chlorophylls with a concommitant fixation of 20×10^{10} tons of carbon dioxide from the atmosphere and oceans. The opposing forces of photosynthesis and respiration results in shuttling of oxygen and carbon dioxide molecules between the atmosphere and living beings. It is estimated that every carbon dioxide molecule gets recycled in hundred years, while an oxygen molecule takes about 1000 years.

Also, an increased carbon dioxide concentration may lead to an elevated global temperatures, by absorbing the infrared radiation, radiated back from the earth. This phenomenon popularly known as the "green house effect" can profoundly alter climate and produce new deserts and elevate sea levels. The chlorophylls and the increased global photosynthesis through aforestation alone could counteract the apparently beneficial but potentially dangerous carbon dioxide elevations.

Human civilisation has taken an irreversible turn with the onset of agricultural practice. With a deliberate cultivation of a few species of plants, all the food energy and most of the fuel can be traced solely to the activity of chlorophyll molecules. Therefore, if evolution had not produced the chlorophyll molecule, life would have remained highly primitive and static. Possibly, it could have exterminated abruptly.

V S. RAMA DAS
D. SUNDARSANAM

Prof. Rama Das is professor of Botany and Dean, School of Biological and Earth Sciences at Sri Venkateswara University, Tirupati. Dr. Sundarsanam is a lecturer in Botany, at the same university.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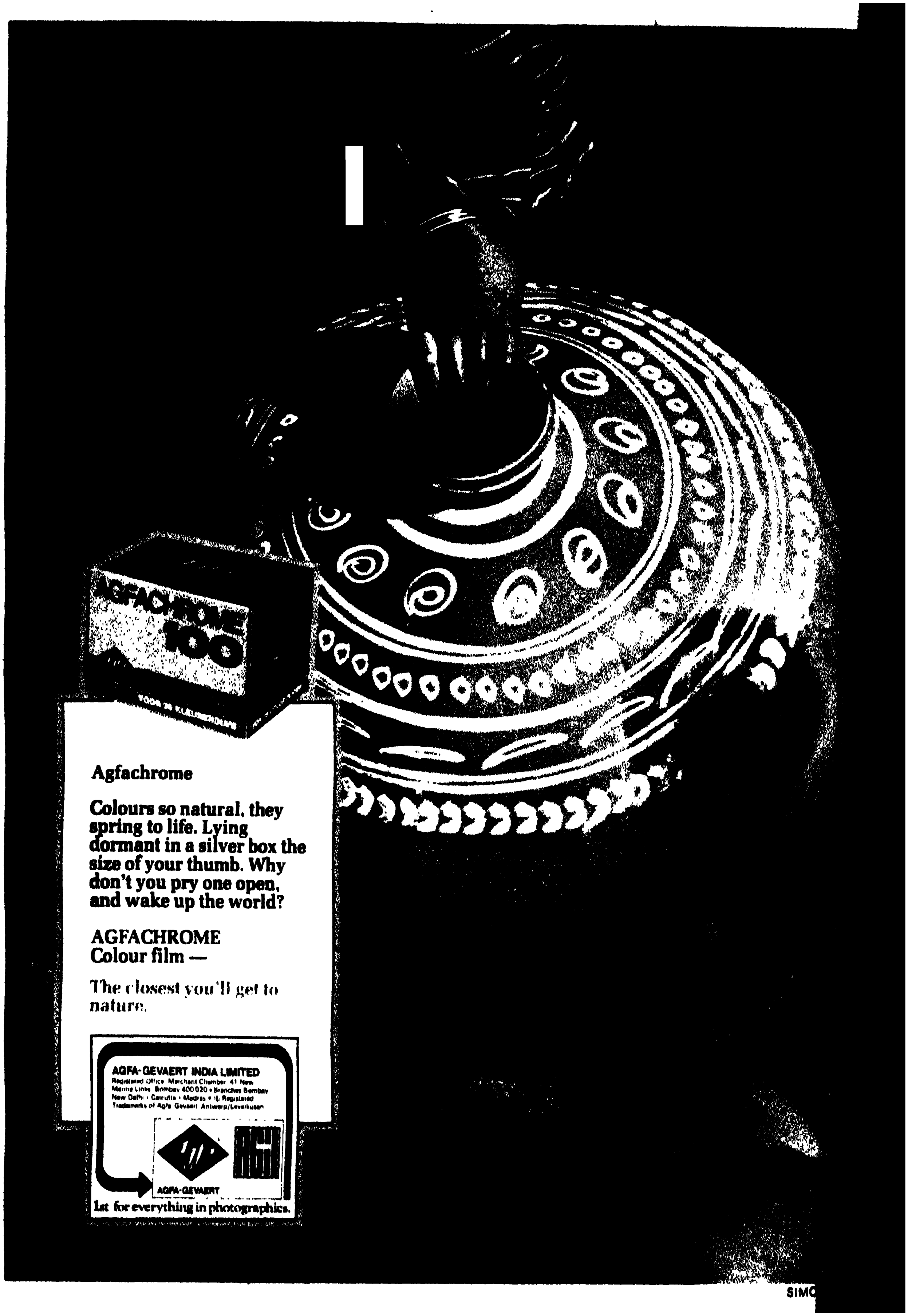

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